NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 550

INDUSTRIAL GASES-GENERATING, HANDLING AND STORAGE

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NOTE

THIS CHAPTER HAS BEEN REFORMATTED FROM DOUBLE COLUMN TO SINGLE COLUMN TO SUPPORT THE NSTM DATABASE. THE CONTENT OF THIS CHAPTER HAS NOT BEEN CHANGED.

CHAPTER 550

INDUSTRIAL GASES-GENERATING, HANDLING, AND STORAGE

SECTION 1.

GASES, COMPRESSED AND LIQUEFIED

550-1.1 SCOPE

550-1.1.1 Instructions in this section apply to all compressed and liquefied gases used onboard naval ships. It is important that these instructions be closely followed. A serious accident may result if gases are improperly identified, mishandled, or used incorrectly. Instructions for specific applications of these gases (e.g., in welding, cutting, and refrigeration) are given in other chapters of this manual. The firefighting use of carbon dioxide, the firefighting agent Halon, and the equipment associated with these gases are covered in detail in **NSTM Chapter 555, Volume 1, Surface Ship Firefighting** .

550-1.2 CHARACTERISTICS OF GASES

550-1.2.1 GENERAL. Specific characteristics of the most commonly used gases are given in paragraphs 550-1.2.2 through 550-1.2.16 and Table 550-1-1. Some gases are referred to as **dry** , **oil-free** (O.F.), or **oil-tolerant** (O.T.). The term **dry** means that the air moisture content is less than 0.02 milligrams per liter. **Oil-free** gas is gas that has not been in contact with oil processing. It may have been compressed by a water-lubricated compressor or converted to gas from a liquefied state by means of a pump-and heat-exchanger system. Most oil-free gases are furnished in the dry state. **Oil-tolerant** gas is gas that may carry traces of oil because it was processed in an oil-lubricated compressor. The term oil-tolerant is used only when a gas is normally supplied in both **oil-free** and **oil-tolerant** grades. Gases that are not labeled oil-free or oil-tolerant are considered to contain oil traces resulting from processing.

550-1.2.1.1 The atmospheric gases obtained from commercial sources and those manufactured in Navy surface ships are produced by the air separation process. In this process, air is compressed and liquefied. The liquefied air is then distilled and separated into its basic components, oxygen and nitrogen. The purity of the gas refers to the percentage by volume of the major constituent. The remaining volume consists of unwanted gas. For example, 100 cubic feet of 99.5-percent-pure oxygen contains 99.5 cubic feet of oxygen and 0.5 cubic feet of nitrogen, argon, and other trace atmospheric gases. Similarly, 100 cubic feet of 99.0-percent-pure nitrogen contains 99 cubic feet of nitrogen and 1.0 cubic feet of oxygen and other trace atmospheric gases. Because the air separation process takes place at a very low temperature, all water vapor is frozen out and the gases are dry. Other trace contaminants that are drawn in with the processed air exist in such small quantities that shipboard analysis is not practical. For most purposes, these trace contaminants are not important. If it is necessary, however, samples should be taken and sent to shore-based laboratories equipped for this analysis.

550-1.2.2 ACETYLENE GAS. Acetylene ($C_2 H_2$) is stable and safe to handle as charged in solution in standard Navy cylinders. In the free gaseous state, it is very unstable and likely to decompose violently. This is particularly true if the acetylene is compressed in nonstandard cylinders. Acetylene has a wide explosive range when mixed with air or oxygen. The explosive limits of acetylene in air range from 2.5 to 81 percent acetylene. The maximum effect is at approximately 7.8 percent. The maximum safe pressure for gaseous acetylene in pipes, manifolds, and elsewhere is 15 pounds per square inch gage (lb/in^2 g). When in the gaseous state and at an unsafe

pressure, acetylene is apt to disassociate violently if subjected to shock or heat. Pressures above 25 lb/in^2 g are especially dangerous. Acetylene shall be generated, handled, and stored in accordance with **NSTM Chapter 074, Volume 1, Welding and Allied Processes** .

550-1.2.3 AIR. Air obtained must be either oil-free or oil-tolerant.

Table 550-1-1. CHARACTERISTICS OF GASES

Name	Symbol	Odor	Flammability (Percent by Volume in Air)		Autoignition Temperature		Density Relative to Air (Air = 1)	Vapor Pressure at 20°C (68°F) (lb/in^2)	Weight in Pounds of 1 Cubic Foot at Standard Atmospheric Pressure and 20°C (68°F)	Physical State when Shipped	Remarks
			Lower	Upper	°C	(°F)					
Acetylene	$C_2 H_2$	Garlic	2.5	81	305	(581)	0.90	663.57	0.06754	Dissolved	Shipped dissolved in acetone at 250 lb/in^2 and 21°C (70°F)
Air	-	None	-	-	-		100	[a]	.07528	Gas	
Ammonia	NH_3	Pungent	16	25	651	(1,204)	.59	124.34	.04420	Liquid	
Argon	A	None	-	-	-		1.38	[a]	.10389	Gas	Inert Gas
Butane	$C_4 H_{10}$ [b]	Rotten cabbage[c]	1.9	8.5	430	(806)	2.00	30.6	.1507	Liquid	
Carbon dioxide	CO_2	None	-	-	-		1.52	830.47	.1142	Liquid	Inert Gas
Refrigerant 12[d]	$CC1_2 F_2$	None	-	-	-		4.17	67.54	3.136	Liquid	Inert Gas
Refrigerant 22[e]	$CHCIF_2$	None	-	-	-		2.98	122.00	.2243	Liquid	Inert Gas
Refrigerant 11[g]	$CC1_3 F$	Faint Ethereal	-	-	-		4.90	3.822[*]	.3621[**]	Liquid	Inert Gas
Refrigerant 114[h]	$C_2 C1_2 F_4$	Faint Ethereal	-	-	-		3.31	11.569	.4638	Liquid	Inert Gas
Ethyl chloride	$C_2 H_5 C1$	Sweet	3.8	15.4	518	(966)	2.21	19.55	.1664	Liquid	
Helium	He	None	-	100	-		.14	[a]	.01039	Gas	Inert Gas
Hydrogen	H_2	None	4	75	580	(1,076)	.07	[a]	.00523	Gas	
Inert gas	-	None	-	-	-		1.05	[a]	.079	-	Inert Gas
Methyl acetylene propadiene (MAPP gas)	$C_3 H_4$	Musty	3.4	10.8[f]	454	(850)	1.48	94	.1131	Liquid	

Table 550-1-1. CHARACTERISTICS OF GASES - Continued

Name	Symbol	Odor	Flammability (Percent by Volume in Air)		Autoignition Temperature		Density Relative to Air (Air = 1)	Vapor Pressure at 20°C (68°F) (lb/in ^{2})	Weight in Pounds of 1 Cubic Foot at Standard Atmospheric Pressure and 20°C (68°F)	Physical State when Shipped	Remarks
			Lower	Upper	°C	(°F)					
Methyl chloride	CH_3 C1	Ether	10.7	17.4	632	(1,170)	1.8	69.82	.1309	Liquid	
Nitrogen	N_2	None	-	-	-		.97	[a]	.07274	Gas	Inert Gas
Nitrous oxide	N_2 O	Ether	-	-	-		1.52	739.41	.1143	Liquid	
Oxygen	O_2	None	-	-	-		1.10	[a]	.08305	Gas	
Propane	C_3 H_8 [b]	Rotten cabbage[c]	2.2	9.6	450	(842)	1.6	129.36	.1143	Liquid	
Sulfur Hexafluoride	C_4 H_{10} [b]	Rotten cabbage[c]	1.9	8.5	461	(861)	5.114	320	.3846	Liquid	

[a.] Gas cannot be liquefied at 20°C (68°F). Cylinder pressure is determined by amount of gas in the cylinder.

[b.] Fuels of which the major constituent has the indicated chemical symbol

[c.] Propane and butane generally are odorless in the pure state, and are artificially odorized as an aid for detecting leaks

[d.] Dichlorodifluoromethane

[e.] Monochlorodifluoromethane

[g.] Trichlorofluoromethane

[*] Pressure below atmosphere

[**] Weight was taken with regard to 26.7°C (80°F)

[h.] Dichlorotetrafluoroethane

[f.] Upper explosive limit

550-1.2.4 AMMONIA. Ammonia (NH_3) is generally used as a refrigerant. The explosive limits of ammonia in air range from 15 to 25 percent ammonia. Ammonia is an irritant and can cause acute distress by attacking the tissues of the respiratory tract, the skin, and the eyes. Exposure to large quantities can be fatal. Moist red litmus paper turns to a blue color when exposed to ammonia, providing a means of identification.

550-1.2.5 ARGON. Argon (A) is an inert gas, slightly heavier than air. Argon does not form flammable or explosive mixtures with air or oxygen, nor will it support combustion or respiration. It is not poisonous, but it can displace oxygen from the atmosphere, thereby causing asphyxia. Argon is used for inert gas shielded welding and is furnished in a dry, oil-free state.

550-1.2.6 CARBON DIOXIDE. Carbon dioxide (CO_2) is a colorless, odorless gas 1.52 times heavier than air. It can be condensed into a colorless liquid and kept under pressure in cylinders. When filled with liquid carbon dioxide at atmospheric pressure, carbon dioxide cylinders are normally filled to 68 percent of the weight of the cylinder water volume. This is required by the **Code of Federal Regulations, title 49, section 173.304** . If allowed to expand suddenly into air, liquid carbon dioxide cools off to the extent that it partially solidifies into a white, snowy mass. The carbon dioxide snow slowly volatilizes, remaining at the constant temperature of -78.3°C (-109°F).

550-1.2.6.1 Although not a poison, carbon dioxide is dangerous when in the atmosphere in concentrations above 4 percent. In such concentrations, carbon dioxide makes the air unfit to breathe, causing headaches and nausea. In higher concentrations, it can cause death as a result of a lack of oxygen. Heavier than air, carbon dioxide remains near the decks and is especially hazardous to personnel when ventilation is inadequate. Because it does not support combustion or form explosive mixtures with any material, it is used chiefly as a fire-extinguishing agent. It is also used as a means for inflating life rafts and safety vests and as a propelling or expelling agent. Other uses are for soft drink carbonation and refrigeration. To verify that a cylinder contains carbon dioxide, invert the cylinder and momentarily open the valve, permitting the gas to flow on the deck or into an open vessel. If solidified carbon dioxide, or snow, is deposited, the cylinder contains carbon dioxide. Cylinders designed for fire fighting need not be inverted.

550-1.2.7 HELIUM. Helium (He) is an inert gas that is used for arc welding and for the inert blanketing of molten metals. It is also used for the inert filling of electrical and optical instruments, to produce helium-oxygen mixtures for breathing, and for meteorological balloon and airship inflation.

550-1.2.8 HYDROGEN. Hydrogen (H_2) is extremely flammable. When in concentrations of less than 10 percent (by volume) in air, hydrogen will burn with an almost invisible blue flame. A hydrogen concentration of between 4 and 75 percent in air by volume may explode when brought in contact with any object having a bright red heat. Hydrogen is not poisonous. It is shipped as a gas in cylinders. It is used in welding and underwater cutting operations and in the past has been used to inflate barrage balloons.

550-1.2.9 INERT GAS. A true inert gas is one which does not react chemically with any substance (e.g., argon and helium). For industrial applications, an inert gas may be defined as a gas, which under given conditions, will not react chemically with any substance present. For purposes of this chapter, an inert gas is one which is nonflammable, will not support combustion, and is normally 82 to 85 percent nitrogen, 12 to 15 percent carbon dioxide, and a maximum of 3 percent oxygen. This gas mixture is generated by the controlled combustion of a hydrocarbon fuel in air until very little oxygen remains, followed by removal of the by-product, water vapor. It is used wherever an inert gas blanket is required, particularly in volatile fuel piping and storage systems. For fire protection applications, this inert gas mixture must contain no more than 3 percent oxygen by volume.

550-1.2.10 LIQUID PETROLEUM GASES. Liquid petroleum gases (e.g., propane and butane) are colorless and odorless in their normal states. It is common practice to odorize the gases artificially. This practice allows leaks to be detected quickly and safeguards personnel. Liquid petroleum gases are not poisonous. However, their fumes have an intoxicating effect similar to that of gasoline fumes. Liquid petroleum gases are flammable when mixed with air in certain proportions (2 to 9.5 percent). When ignited, under certain conditions, they may cause explosions similar to those produced by gasoline. Liquid petroleum gases are heavier than air, will seek ground level, and will settle in pits. Industrially, they are used for furnace work, general heating, metal cutting, and brazing. Aboard ship, these gases are used principally in dental laboratories and similar installations.

550-1.2.11 METHYLACETYLENE-PROPADIENE (STABILIZED MIXTURE). Methylacetylene-propadiene ($C_3 H_4$) is a fuel gas mixture that is more commonly known by its proprietary name, MAPP gas. It is a clear, colorless liquefied gas with heating characteristics similar to those of acetylene. In many instances, MAPP is used instead of acetylene for cutting, welding, and brazing. MAPP is more stable than acetylene. It will not decompose violently as will acetylene and it does not have as wide an explosive range when mixed with air or oxygen. In air, the explosive limits of MAPP range from 3.4 to 10.8 percent. Because of MAPP's musty smell, small leaks with MAPP concentrations as low as 100 parts per million (p/m) can be detected by most persons. MAPP may be piped and manifolded at cylinder pressure. However, because it can form explosive acetylides just as acetylene does, the material requirements for piping and manifolds shall be as specified in **NSTM Chapter 074, Volume 1, Welding and Allied Processes** .

550-1.2.12 NITROGEN. Nitrogen (N_2) is an inert gas, slightly lighter than air. It does not form flammable or explosive mixtures with air or oxygen, nor will it support combustion or respiration. It is not poisonous but is capable of displacing oxygen from the atmosphere, thereby causing asphyxia. Nitrogen is used for pressure-operated mechanisms such as recoil systems, in optical instrument applications, and for testing and purging pipe lines. It is also used wherever an inert gas-blanket is required such as in atmospheric-controlled furnaces and fuel storage systems and in preservation packing. Nitrogen may be obtained in either a dry, oil-free state, or a dry, oil-tolerant state.

550-1.2.13 NITROUS OXIDE. Nitrous oxide (N_2 O) is used as an anesthetic. It provides a rapid source of anesthesia for operations of short duration. As do most anesthetics, nitrous oxide usually affects exposed personnel in three stages. The first stage is characterized by vertigo. The second stage may be marked by excitement and nausea, but frequently these symptoms are not obvious. The third stage is characterized by calm and muscular relaxation. In this third stage, respiration is quiet and regular, and sensation disappears. During recovery, exposed personnel pass through the 3 stages in reverse order.

550-1.2.14 OXYGEN. Oxygen (O_2) is nonflammable, but is required by the combustion process and intensifies combustion. Contamination with any fuel such as acetylene, hydrogen, oils, or grease may result in a serious fire or explosion. No combustible material should be allowed to come into contact with compressed oxygen. All oxygen in cylinders is of the same purity and is suitable for breathing. Oxygen received through supply channels is normally in one of two types. The first type is aviators' breathing oxygen, which must be dry to prevent freezing at the low temperatures experienced during high-altitude flying. The second type is industrial or technical oxygen, which does not require the low-moisture content. This second type is used for medical purposes and welding and cutting operations. Except for medical use, activities afloat shall requisition and store only aviators' breathing-quality oxygen. Aviators' breathing oxygen may be used for all purposes for which oxygen is required. Submarines may accept bulk breathing oxygen produced aboard submarine tenders if it has a purity no lower than 98 percent. Purity slightly lower than 100 percent has no ill effect other than to reduce the amount of oxygen onboard.

550-1.2.15 REFRIGERANTS. Refrigerants are a group of halogenated hydrocarbons. In the past, members of this group have been widely known by the proprietary name Freon. Several manufacturers now market these materials under various trade names such as Genetron, Ucon, Freon, and Isotron. However, these products are still identified by the refrigerant numbering designations such as 11, 12, 22, 113, and 114. The refrigeration industry has standardized on the use of Refrigerant 12, Refrigerant 22, and other refrigerants. These refrigerants are nonflammable, relatively nontoxic, in smaller concentrations, and nonexplosive. However, in the presence of fire or red-hot metal, they decompose. The decomposition products are extremely toxic. Refrigerants are toxic in high concentrations. Since refrigerants are heavier than air, they will displace air, thus causing an asphyxiation hazard in confined spaces. For specific safety precautions on refrigerants and more detailed information, see **NSTM Chapter 516, Refrigeration Systems** .

550-1.2.16 SULFUR HEXAFLUORIDE. Sulfur hexafluoride (SF_6) is a colorless, odorless, nontoxic gas; it is supplied as a liquefied gas at 320 lbs/in^2 and 20°C (68°F). It is used chiefly as an insulating medium for high-voltage electric and electronic equipment. A specific application is the pressurization of wave guides for fire-control radar. Sulfur hexafluoride has a low order of inhalation toxicity. However, it can cause asphyxiation by displacing the oxygen in the breathing atmosphere.

550-1.3 LIQUEFIED GASES

550-1.3.1 LIQUID NITROGEN. Liquid nitrogen is a colorless, transparent fluid with a boiling point of -196°C (-320°F) and a specific gravity of 0.808 at one atmosphere absolute. It expands to about 700 times its fluid volume when vaporized to a gas at 21.1°C (70°F) and 14.7 lb/in^2 g (atmospheric pressure).

550-1.3.1.1 Liquid nitrogen is used as a low-temperature refrigerant in some fire control systems. It is also used in the freeze sealing of liquid-filled piping during repair work. For information on the freeze-sealing procedure, consult NAVSEA 0348-LP-159-1000, **Freeze Sealing Manual** .

550-1.3.2 LIQUID OXYGEN. For complete information on liquid oxygen, see Section 6.

550-1.4 SAFETY RULES AND INFORMATION FOR SPECIFIC SHIPBOARD GASES

550-1.4.1 GENERAL. Do not use hard pipe to transport compressed gas of any kind to the interior spaces of the ship without specific approval from the Commander, Naval Sea Systems Command (NAVSEA). When using, handling, or storing shipboard gases, those safety precautions outlined in paragraphs 550-1.4.2 through 550-1.4.11 shall be followed.

550-1.4.2 ACETYLENE. Do not discharge acetylene into hose lines, manifolds, or elsewhere at a pressure greater than 15 lb/in^2 g. Use a suitable pressure reducing regulator on all occasions. Acetylene is inherently unstable and, at pressures greater than 15 lb/in^2 g, may disassociate violently when subjected to heat or shock.

550-1.4.2.1 Use acetylene cylinders in the upright position, valve end up. This prevents the possibility of withdrawing acetone when the cylinders are being discharged. After an acetylene cylinder has been stored in the horizontal position, place the cylinder in an upright position, valve end up. Secure the cylinder in this position for a 2-hour period prior to any use. If acetone still flows from the cylinder when the cylinder is used, secure the cylinder for an additional 2 hours.

550-1.4.2.2 Do not recharge acetylene cylinders or transfer acetylene from one cylinder to another without specific approval from NAVSEA. Acetylene cylinders can be safely charged or refilled only with special equipment. Furthermore, acetylene cylinders are specially manufactured. A porous material with tiny cellular spaces is packed into each cylinder. As a result, there are no pockets of significant size where free acetylene in the gaseous state may collect. In addition, acetone partially fills the cellular spaces and acts as a solvent for the acetylene. Acetylene is highly soluble in acetone, making possible the storage of large volumes in the dissolved state. While in this dissolved state, acetylene is stable. Because of their special design, only acetylene cylinders should be used to store acetylene gas.

550-1.4.2.3 Keep sparks and flames away from acetylene cylinders. Under no circumstances allow a flame to come in contact with safety devices.

550-1.4.2.4 If it is necessary to test for leaks, use soapy water.

550-1.4.2.5 Do not interchange acetylene regulators, hose, or other appliances with similar equipment intended for other gases. Use only those manifolds that are approved for use with acetylene by NAVSEA.

550-1.4.3 ANHYDROUS AMMONIA. Anhydrous ammonia is seldom used aboard ships. Prior to shipboard use, refer to ASA K61.1, **American Standard Safety Requirements for the Storage and Handling of Anhydrous Ammonia** . This pamphlet is published by the Compressed Gas Association, Inc., as CGA G-2.1.

550-1.4.4 CARBON DIOXIDE. Although not a poison, carbon dioxide is a dangerous asphyxiant because it is not detectable by odor or color. When carbon dioxide is present in hazardous quantities, personnel may be overcome with little or no warning. Heavier than air, it remains near the deck and is especially hazardous to personnel when ventilation is inadequate. The inhalation of carbon dioxide will produce various effects, depending on the length of time the carbon dioxide is breathed. Small percentages of carbon dioxide cause tiredness and perhaps headaches; 3 percent carbon dioxide in the air doubles the breathing effort. Panting will result from exposure to 5 percent carbon dioxide. Eight percent carbon dioxide causes marked distress. Ten percent carbon dioxide causes unconsciousness very quickly, and may result in permanent injuries to the heart and brain. Exposure to higher percentages of carbon dioxide may result in death.

550-1.4.4.1 To treat exposed personnel, administer artificial respiration and oxygen as required, and keep the patient warm and quiet.

550-1.4.4.2 Do not enter an area or compartment containing hazardous amounts of carbon dioxide without being equipped with a breathing mask and an independent oxygen supply. For precautions to be observed prior to entering hazardous atmospheres, see **NSTM Chapter 074, Volume 3, Gas Free Engineering** .

550-1.4.5 COMBUSTIBLE GASES. The same safety rules apply to combustible gases (liquid petroleum gas, hydrogen, methyl chloride) as are outlined for acetylene. The only exception is that these gases are stable and will not disassociate at pressures above 15 lb/in^2 g.

550-1.4.6 INERT GASES. Helium, nitrogen, carbon dioxide, and argon are nonflammable gases and may be stowed with flammable gases. Because of the inert characteristics, these gases provide fire protection. However, they will not support respiration and, if present in sufficient concentrations in closed spaces, will cause asphyxiation.

550-1.4.7 GASEOUS NITROGEN. Safety rules for the use of gaseous nitrogen are similar to those cited for other nonflammable, nonoxidizing, and nontoxic compressed gases. Do not discharge large quantities of this gas into closed compartments unless adequate ventilation is provided (see paragraphs 550-1.4.4.2 and 550-1.4.10).

550-1.4.8 LIQUID NITROGEN. For safety rules covering liquid nitrogen, see Section 6.

550-1.4.9 OXYGEN. For safety rules covering both gaseous and liquefied oxygen, see Section 6.

550-1.4.10 OXYGEN DEFICIENCY. Excessive concentrations of asphyxiant gases such as carbon dioxide, nitrogen, and argon in air are equivalent to an oxygen deficiency. The time it takes to develop adverse effects because of low oxygen concentration will vary. In general, the greater the oxygen deficiency, the shorter the time for the onset of symptoms. For example, total deprivation of oxygen may cause loss of consciousness in 60 seconds or less. Sudden depletion of oxygen to a concentration of 12 percent may produce unconsciousness in 10 minutes or less. Above a concentration of 15 percent, loss of consciousness will probably not occur. Symptoms of low oxygen concentrations are given in Table 550-1-2.

550-1.4.11 REFRIGERANTS. When servicing refrigeration systems with refrigerant, (e.g., R_{12} or R_{22}) always wear safety goggles. Goggles eliminate the possibility of liquid refrigerant coming in contact with the eyes and causing injury as a result of the freezing effect of the liquid. High concentrations of refrigerant gas may displace enough air to cause a lack of sufficient oxygen in working spaces. Treat personnel overcome by lack of oxygen by moving them into fresh air, and, if required, give artificial respiration.

Table 550-1-2. EFFECTS OF LOW OXYGEN CONCENTRATION

Oxygen Concentration *		Effect
Partial Pressure (Millimeters of Mercury or Torr)	**Volume (Percent)**	
122-140	16-18	Increased breathing rate, lack of coordination
106-122	14-16	Easily tired, easily upset emotionally, possible loss of feeling of pain upon injury, abnormal fatigue from exertion
76-106	10-14	Lethargic, apathetic, confused thinking, physical collapse, unconsciousness, nausea, and vomiting
76 or less	10 or less	Convulsive movements, gasping, breathing stops

*At Standard Pressure (760 millimeters of mercury)

SECTION 2.

GAS CYLINDERS AND CYLINDER VALVES

550-2.1 PROCUREMENT

550-2.1.1 Gases, cylinders, valves, and spare parts shall be procured from the supply system whenever practical.

550-2.1.2 Prior to departure for foreign ports, ships should obtain government-owned compressed gas cylinders in sufficient quantities to cover mission requirements. Purchases of foreign-made cylinders should be avoided except in cases of emergency. If the purchase of foreign-made cylinders becomes necessary, these cylinders

should be transferred to a supply depot as soon as practical upon returning to the United States. The Department of Transportation (DOT) regulations require specific approval for interstate transportation of foreign cylinders. All cylinders of foreign manufacture are to be turned in to the nearest depot to be surveyed for scrap. The Department of Transportation (DOT) has succeeded the Interstate Commerce Commission (ICC) as the authority in charge of compressed gas cylinder policy. Every previous rule, regulation, specification, and gas cylinder marking is valid and remains in effect unless specifically superseded by a new or amended DOT document.

550-2.1.3 In 1963, the Defense Supply Agency became the single service manager for commercial and industrial gas cylinders, Federal Supply Classification (FSC) Class 8120, and for chemical material, FSC group 68, which includes gases. Requisitions for cylinders, gases, cylinder valves, and caps should be handled by the cognizant supply activity.

550-2.2 SERIAL NUMBERS

550-2.2.1 When the Defense Supply Agency assumed cognizance of gas cylinders in 1963, it was decided that government serial numbers would no longer be required on all new cylinders. All cylinders that had been owned by the Navy are identified by a Navy serial number indented thereon, preceded and followed by the letters USN. Cylinders more than 2 inches in diameter are currently required by DOT regulations to be marked (stamped) with serial numbers. Cylinders 2 inches or less in diameter may be given manufacturers' lot numbers, with not over 500 cylinders in each lot. DOT8 cylinders of all sizes require serial numbers.

550-2.3 DEPARTMENT OF TRANSPORTATION IDENTIFYING MARKINGS

550-2.3.1 Gas cylinders are manufactured and maintained in accordance with DOT regulations, as well as the applicable government specifications mentioned in this section. To assist in carrying out DOT regulations, each applicable cylinder is marked (stamped) or stenciled with DOT and Navy identifying markers. Compressed gas cylinders in the Navy supply system are marked (stamped) with figures and letters as follows:

a. One side
   1. **DOT** mark and **SPUN** when spun cylinders are so manufactured.
   2. Manufacturer's symbol, serial number, letter, and nonshat if cylinder is the nonshatterable type.
   3. Third party inspection mark and Navy Inspector's stamp.

b. Other side
   1. Specification number and date (month and year).
   2. Bare weight of cylinder in pounds (if required).
   3. Original and subsequent test dates - month and years. The symbol of the testing agency is placed between the month and year by most testing facilities, e.g., 05 F 67.

550-2.4 PHYSICAL PROPERTIES

550-2.4.1 The characteristics of commonly used cylinders are given in Table 550-2-1. Compressed gas cylinders covered by DOT specifications are often made from special alloy steel. Many cylinders are specifically designed to have unique physical characteristics. To avoid impairing these special characteristics, such cylinders shall not be welded, hot or cold worked, shaped, or otherwise altered.

550-2.5 CYLINDER VALVES

550-2.5.1 BASIC DESIGNS. Navy standard valves are of two basic designs: packed valves, and diaphragm-type packless valves.

550-2.5.1.1 Packed Valves. Packed valves require a packing material around the valve stem to prevent leakage. A cutaway view of a packed valve is given in Figure 550-2-1. The valve stem is packed to prevent gas leakage when the valve is opened. Some cylinder valves have wrench-operated spindles instead of hand wheels. For permissible packing materials, see MIL-V-2.

550-2.5.1.2 Packless Valves. Packless valves are sealed against leakage around the valve stem by flexible metallic diaphragms securely clamped to the valve bonnets (see Figure 550-2-2). The basic packless valve design may be categorized into two types: the nonbackseating type and the backseating type. The nonbackseating type is designed so that the metallic sealing diaphragms may not be replaced under pressure. In the backseating type, these metallic diaphragms may be replaced. This can be done without undue hazard or loss of contained gases if the outlet cap is in place and secure.

550-2.5.1.2.1 Replace diaphragms in packless valves only with spare diaphragms specifically designed for these valves. Diaphragms are fabricated from materials specifically selected for service at high pressure while dynamically loaded. They are often of a design suitable for use only with valves fabricated by a given manufacturer and for a specific gas.

550-2.5.2 VALVE IDENTIFICATION. Navy standard valves and commercial-type valves are identified as described in paragraphs 550-2.5.2.1 and 550-2.5.2.2, respectively.

550-2.5.2.1 Navy Standard Valves. Valves manufactured in accordance with the latest provisions of MIL-V-2 are labeled. The name of the gas or service for which they are designed is indented on at least one of the flats on the sides of the valves (see Figure 550-2-3). Valves shall be used only for a service and with gases or liquids as indicated. Their use shall comply with specific valve outlet design. Use other than as indicated is hazardous and may result in injury to personnel or damage to equipment. Valves manufactured in accordance with earlier, and now obsolete, specifications were not identified by the name of the gas. Thread sizes for the most commonly used gases are given in Table 550-2-2. Medical-type yoke valves are fitted with a pin indexing system so that they may be attached only to the system for which they are intended.

550-2.5.2.2 Commercial-Type Valves. Commercial type valves have been fitted to government-owned cylinders when Navy-type valves are not available. In a number of cases, the valve design is in accordance with the manufacturer’s specifications. This does not detract from the serviceability of the valve.

550-2.5.3 SAFETY DEVICES. Government specifications and DOT regulations require that valves designed for certain services be fitted with safety devices. These devices act as a safeguard against the buildup of hazardous pressures within cylinders. Without these devices, dangerous pressure may result from such conditions as exposure to heat and over-charging. Details of safety devices for specific valves may be found in MIL-V-2. In general, these safety devices may be divided into four categories based on functional design: fusible plugs, spring-loaded safety devices, unbacked safety caps with rupture disks, and backed safety caps with rupture disks.

550-2.5.3.1 Fusible Plugs. Fusible plugs are threaded hexhead plugs with centers that are fitted with fusible metal. When the cylinder is subjected to high temperatures, the fusible metal melts. This permits gas to escape through the channel previously filled with the metal. This permits gas to escape through the channel previously filled with the metal. Fusible plugs are used as safety devices on refrigerant and acetylene valves.

Table 550-2-1. CHARACTERISTICS OF COMMONLY USED CYLINDERS

Service	Capacity Approx.*	Working Pressure (Pounds per Square Inch)	DOT Specification	Diameter (Inches)	Length (Add 6 Inches for cap) (Inches)	Empty Weight (Approximate) (Pounds)	Periodic Test Required	Outlet Connection (Inches)
Acetylene	10 ft^3	250	8	4	12-1/2	**	No	3/8
	40 ft^3	250	8 or 8AL	6	20	**	No	3/8
	50 ft^3	250	8 or 8AL	7	22	**	No	1
	225 ft^3	250	8AL	12	29	**	No	1
Air	100-226ft^3	1,800-2,265	3 or 3AA	9	51	130	Yes	3/4
Ammonia	45 lbs	480	4A	10-1/4	37	130-140	Yes	3/4
	100 lbs	480	4AA	12	53	105	Yes	3/4 and 1
	150 lbs	480	3A or 4AA	14.5 to 15	51 to 52.5	160	Yes	3/4
Argon	197-250ft^3	1,8001-2,265	3A or 3AA	9	51	130	Yes	3/4
Butane	119 lbs	240	4BA or 4E	14.5	44	75	Yes	3/4
Carbon dioxide (storage)	20 lbs	2,015	3AA	6.75	29	45	Yes	3/4
	50 lbs	1,800-1,015	3A or 3AA	8-1/2	51	100	Yes	3/4
Carbon dioxide	50 lbs	2,015	3A or 3AA	8-1/2	51	10***	Yes	1
(fire extinguisher)***	35 lbs	2,015	3A or 3AA	8-1/2	34	90	Yes	1
	15 lbs	2,015	3A or 3AA	6-1/4	21	45	Yes	1
Carboxide (fumigant-carbon dioxide-ethylene mixture)	60 lbs	2,015	3AA	8 to 9	49 to 53	130	Yes	3/4
Helium	170-220ft^3	1,800-2,265	3A or 3AA	9	51	130	Yes	3/4
Hydrogen	176-220ft^3	1,800-2,265	3A or 3AA	9	51	130	Yes	3/4
Methylacetylene-propadiene (MAPP gas)	7.5 lbs	300	4E	5.5	20	7.5	Yes	3/4
	70 lbs	240	4BW	12	44	5.5	Yes	3/4
Nitrogen	184 ft^3	1,800-2,265	ICC3 or 3AA	9	51	110-115	Yes	3/4
Oxygen	200-240 ft^3	1,800-2,265	3A or 3AA	9	51	110-115	Yes	3/4
	27 ft^3	2,265	3A or 3AA	5-3/8	18.5	20	Yes	3/4
	48 ft^3	2,265	3A or 3AA	7	19.5	30	Yes	3/4
	300 ft^3	2,400	3AA	9.25	55	145	Yes	3/4

Table 550-2-1. CHARACTERISTICS OF COMMONLY USED CYLINDERS - Continued

Service	Capacity Approx.*	Working Pressure (Pounds per Square Inch)	DOT Specification	Diameter (Inches)	Length (Add 6 Inches for cap) (Inches)	Empty Weight (Approximate) (Pounds)	Periodic Test Required	Outlet Connection (Inches)
Propane	40 lbs	240	4BA or 4BW	12.25	28	40	Yes	3/4
	100 lbs	240	4BA or 4BW	14.5	44	75	Yes	3/4
	200 lbs	240	4B or 4BA	19	52.5	170	Yes	3/4
Refrigerants	10 lbs	300	4BA	6-3/4	11	16	Yes	3/4
	50 lbs	300	4B or 4BA	8-3/16	27	25	Yes	3/4
Sulfur hexafluoride	8.3 lbs	2,015	3A or 3AA				Yes	3/4
	25 lbs	2,015	3A or 3AA				Yes	3/4
	115 lbs	2,015	3A or 3AA	9	51	115	Yes	3/4

*Where capacities are expressed in cubic feet, the volumes shown are those of the gas after withdrawal from the cylinder at atmospheric pressure and normal room temperature.

**Empty weight is normally stamped on the shoulder of the cylinders.

***For complete information on fire extinguisher carbon dioxide cylinders, see NSTM Chapter 555, Firefighting. Actual weights, charged and empty, will be found stamped on cylinder valve.

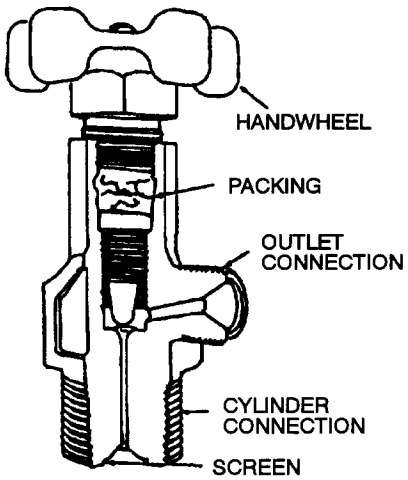

Figure 550-2-1. Cutaway View of a Packed Cylinder Valve

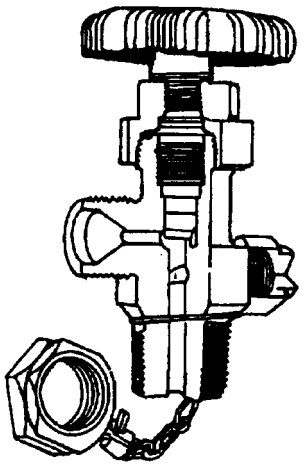

Figure 550-2-2. Cutaway View of Oxygen Cylinder Packless (Diaphragm-Type) Valve

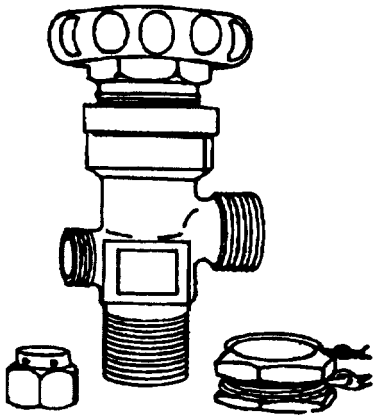

Figure 550-2-3. Oxygen Cylinder Valve

Table 550-2-2. COMPRESSED GAS CYLINDER VALVE OUTLETS COMMONLY USED ABOARD SHIP

Service	Outlet Thread				Mating Thread				
	Thread Diameter (Inches)	**Direction Threads**	**Threads per Inch**	**Type Threads**	**Thread Diameter (Inches)**	**Direction Threads**	**Threads per Inch**	**Type Threads**	**MIL-V-2 Valve Type**
Acetylene	0.885	LH	14	F	0.880	LH	14	M	V2-511
Air, oil-free	.825	RH	14	M	.830	RH	14	F	V5-1341
Air, oil-tolerant	.965	LH	14	F	.980	LH	14	M	V6-591
Argon: Oil-free	.965	RH	14	F	.960	RH	14	M	V11-581

Table 550-2-2. COMPRESSED GAS CYLINDER VALVE OUTLETS

COMMONLY USED ABOARD SHIP - Continued

Service	Outlet Thread				Mating Thread				
	Thread Diameter (Inches)	**Direction Threads**	**Threads per Inch**	**Type Threads**	**Thread Diameter (Inches)**	**Direction Threads**	**Threads per Inch**	**Type Threads**	**MIL-V-2 Valve Type**
Butane	.885	LH	14	F	.880	LH	14	M	V14-511
Carbon Dioxide	.825	RH	14	M	.830	RH	14	F	V15-321
Refrigerant	1.030	RH	14	M	1.035	RH	14	F	V22-621
Helium: Oil-free Oil-tolerant	0.965 .965	RH LH	14 14	F F	0.960 .960	RH LH	14 14	M M	V11-581 V26-591
Hydrogen	.825	LH	14	M	.830	LH	14	F	V29-351
Nitrogen: Oil-free Oil-tolerant	.965 .965	RH LH	14 14	F F	.960 .960	RH LH	14 14	M M	V11-581 V26-591
Nitrous Oxide	.825	RH	14	M	.830	RH	14	F	V37-1320
Oxygen	.903	RH	14	M	.908	RH	14	F	V39-541
Propane	.885	LH	14	F	.880	LH	14	M	V14-511
Sulfur Hexafluoride	.965	LH	14	F	.960	LH	14	M	V46-591

550-2.5.3.2 Spring-Loaded Safety Devices. Spring-loaded safety devices usually function as pop valves. These devices work when internal pressures in cylinders overcome spring tension, permitting gas to escape. Devices of this sort are used on liquefied petroleum gas valves. They operate generally at about 156 percent of the charging pressure indicated for the cylinders (DOT-approved pressure).

550-2.5.3.3 Unbacked Safety Caps with Rupture Disks. Unbacked safety caps with rupture disks consist essentially of a safety cap covering a safety port in the valves. The cap retains a frangible disk firmly over the safety port. Under excessive pressure (2,600-3,000 pounds per square inch (lb/in^2)), the safety disk ruptures and allows the gas in the cylinder to vent to the atmosphere. This type of safety device is used in carbon dioxide service.

550-2.5.3.4 Backed Safety Caps with Rupture Disks. Backed safety caps with rupture disks are essentially the same as the unbacked variety. In backed caps, however, fusible metal supports the frangible disk that blocks off escape ports. In practice, if the cylinder, the valve, and the fusible metal are heated above the melting temperature and the pressure within the cylinders is or approaches 2,600-3,000 lb/in^2, the frangible disk will rupture and

reduce the pressure. This type of device is commonly used on gaseous air, helium, hydrogen, nitrogen, and oxygen valves. However, the backed disk safety device is prohibited on cryogenic services for air, helium, hydrogen, nitrogen, and oxygen.

550-2.6 CYLINDER PAINTING

550-2.6.1 COLOR CODE. All government-owned compressed-gas cylinders are required to be painted to minimize corrosion. Cylinders shall be painted and stenciled in conformance with MIL-STD-101. The purpose of the color code outlined in MIL-STD-101 is to identify hazards presented by cylinder contents. The code should not be used for specific identification of contents. Contents shall be identified only by the stenciled name and decals on the cylinder (see paragraph 550-2.6.5).

550-2.6.2 FREQUENCY. It is the responsibility of all ships and commands to preserve cylinders. Repaint cylinders only as often as necessary for preservation. (Do not repaint an entire cylinder if touch up will provide adequate preservation.) Never use painting as a substitute for cleaning dirty cylinders.

550-2.6.3 RESTRICTION. Paint cylinders only the colors authorized in MIL-STD-101. If these colors do not match the camouflage scheme of the ship, canvas or other material painted with camouflage colors may be placed over the cylinders.

550-2.6.4 PROCEDURE. Prior to painting cylinders, remove all loose paint, scale, and rust. If this requires the use of wire brushes, metallic scrapers, or other spark-producing tools, use them in the open or in a well-ventilated compartment equipped with ample firefighting equipment. Prior to any cleaning operation, test the valves, safety devices, and fusible plugs of cylinders containing flammable gases. Testing these components with soapy water will pinpoint leaks. Do not clean leaking cylinders. Instead, tag them with the identified problem and return them to an authorized repair activity.

550-2.6.4.1 Never paint internal surfaces of cylinders. Take care to keep valves free from paint. Do not paint over serial numbers or test markings. If necessary, carefully scrape these indented figures and letters to remove any imbedded paints and foreign matter to bring the markings into relief. Follow applicable methods given in **NSTM Chapter 631, Preservation of Ships in Service (Surface Preparation and Painting)** .

550-2.6.5 DECALCOMANIAS. In addition to the lettering and colors prescribed in MIL-STD-101, two decalcomanias are applied opposite each other on the shoulder of each cylinder. Decals must conform to NAVSHIPS dwg 810–1385867.

550-2.7 PREVENTIVE MAINTENANCE

550-2.7.1 If Planned Maintenance System (PMS) is installed, conduct shipboard cylinder preventive maintenance in accordance with Maintenance Requirement Cards (MRC’s).

550-2.8 REPAIRS

550-2.8.1 DEFECTIVE CYLINDERS. Cylinders shall be repaired only by activities that are specifically authorized to perform such work. To ensure that all cylinders onboard a ship are in satisfactory and serviceable con-

dition, conduct periodic inspections. Depressurize (see paragraph 550-2.8.2) and exchange at the nearest naval supply depot all cylinders found to have any of the following defects:

Severe dents, gouges, or corrosion

Evidence of fire damage (carbon deposits on valves or safety plugs of cylinders containing acetylene or other flammable gases)

Bulges (deformation of cylinders from internal pressures)

Damaged, split, or leaking seams (low-pressure cylinders containing flammable gases such as acetylene.

550-2.8.1.1 If it is impractical to bleed defective cylinders, survey the cylinders and jettison them at sea. Submit an approved survey report as required for survey of ship's materials.

550-2.8.2 DEFECTIVE VALVES. Return cylinders with leaking or defective valves (e.g., stripped threads or bent stems) to the nearest naval supply depot for overhaul. Leakage from a valve may be caused by the presence of dirt or foreign particles in the valve or on the valve seat. If this is the case, leakage may sometimes be corrected by partially opening and then closing the valve to blow out the foreign material. If the leakage continues, remove the cylinder to a safe place (in the open if possible). Drain the cylinder by opening the valve carefully, as directed in paragraphs 550-2.8.3 and 550-2.8.4. After the valve is closed tightly, tag the cylinder and turn it in for overhaul and recharging.

550-2.8.3 CYLINDERS CONTAINING COMBUSTIBLE OR TOXIC GASES. Use pressure regulators to drain cylinders containing combustible or toxic gases such as acetylene and hydrogen. Control discharge rate in order to prevent dangerous accumulations of these gases.

550-2.8.4 CYLINDERS CONTAINING TOXIC OR IRRITANT GASES. Exercise the utmost caution in draining cylinders containing anhydrous ammonia and other toxic or irritant gases. Discharge these cylinders to the atmosphere only under controlled conditions. Discharge cylinders in a leeward direction only if the prompt dispersal of gases, without hazard to personnel or equipment, is assured. Equip personnel engaged in draining these cylinders with the necessary protective clothing, goggles, and respiratory protection.

550-2.9 QUINQUENNIAL TESTING OF CYLINDERS

550-2.9.1 REQUIREMENTS. Department of Transportation regulations require that practically all cylinders except acetylene cylinders be retested every 5 years. Regulations specify that cylinders due for prescribed retests must not be charged and shipped until properly retested. If more than 12 years have passed since the last test, the cylinder is discharged and returned to the registered owner for retesting.

550-2.9.2 FACILITIES. Quinquennial tests are performed by naval activities and civilian concerns under DOT regulations that require special, approved testing equipment. Because ships are not authorized to conduct these tests, they are responsible only for returning empty cylinders with expired test periods to the nearest naval supply depot. Returned cylinders must be clearly marked **For Retest** . The following naval activities are authorized to conduct quinquennial tests:

Naval Shipyards:
Norfolk

Mare Island
Puget Sound
Charleston
Pearl Harbor

Naval Base:
Guam, MI
Guantanamo Bay,
Cuba (CO_2 only)

550-2.10 CYLINDER HANDLING

550-2.10.1 CARE IN HANDLING. Handle cylinders that contain flammable or explosive gases with particular care. Make every effort to avoid their being dropped or allowed to strike forcibly against each other or any other object. Take every precaution to prevent bumping or striking the discharge valves during handling operations.

550-2.10.2 CYLINDER CAPS. Ensure that the cylinder valve outlet cap and the cylinder valve protecting cap are both in place when cylinders are being handled. Unless ready-service cylinders are secured in a special portable rack, remove regulators and replace caps before moving cylinders to a new location.

550-2.10.3 CYLINDER TRANSPORT. When loading or transferring cylinders, use a crane, forklift derrick, or handcart when available (ensure that cylinder is secured firmly before moving). Never use electromagnets. If moving a cylinder by hand, tilt the cylinder slightly and roll on its bottom edge, without dragging or sliding. Do not use hooks or lines through the valve protection cap to hoist cylinders. Never lift or carry cylinders by the protective cap. Do not attempt to pry loose with crowbars or similar tools cylinders that are frozen to the deck or otherwise immobilized. Use lukewarm water to unfreeze cylinders.

550-2.11 COMPRESSED GAS STOWAGE

550-2.11.1 GENERAL. In this chapter, the term stowage refers to gas-related cargo articles that are being transported or that are under the cognizance of the Supply Officer until drawn for the ship's own use. It does not refer to articles removed from stores or cargo and transferred to shops or other locations for ready service (see paragraph 550–2.12).

550-2.11.2 GENERAL REQUIREMENTS AND PRECAUTIONS. The following requirements and precautions shall be followed when stowing compressed gas cylinders.

a. Aboard all ships except cargo ships, stow compressed gases only in compartments designated for cylinder storage as shown in applicable plans for the ship.

b. If provisions are made for mechanical ventilation, operate this ventilation in accordance with the damage control classification assigned. The classification for closure of this system shall be Z or W.

c. Ensure that fumes of leaking gas cylinders will not enter ventilation air intakes leading to spaces where personnel may be affected or flammable gases may cause explosions. Ventilate compartments containing compressed gases for 15 minutes prior to entry. This will ensure adequate ventilation in the event ventilation has

been closed down. Prominently post a suitable sign to this effect on the outside of the access door. For instructions covering ready service cylinders, see paragraph 550-2.11.6.

d. In compartments designated for the stowage of flammable or explosive gases, do not permit portable electric wiring or equipment.

e. Keep flammable materials, especially grease and oil, out of stowage compartments and keep compartments clean.

f. Take all necessary precautions to prevent the temperature of stowage compartments from exceeding 54.4°C (130°F).

g. Fasten each individual cylinder securely in the vertical position (valve end up) by means such as metal collars.

h. Stow oxygen in compartments separate from flammable gases. Inert or nonflammable gases (i. e., helium, nitrogen, carbon dioxide, and argon) on the other hand, may be stowed in any compartment designated for compressed gas stowage.

i. Stow full cylinders by date of receipt; place into service in the order received from the supply source.

j. Tag empty cylinders as empty and segregate them from full cylinders. Tightly close cylinder valves and securely fasten valve protection caps to ensure that empty cylinders will be returned to suppliers in good condition. Empty cylinders that are stored with valves securely closed and valve protection caps in place are comparatively less hazardous than full cylinders. However, it is important to handle and stow these empty cylinders with the same caution as if they were full. According to regulations, some gas cylinders are not to be completely exhausted. These cylinders are to be considered empty when the gas pressure falls to approximately 25 lb/in^2 g.

550-2.11.3 OXYGEN STOWAGE. Stow oxygen containers only in designated, well-ventilated spaces. If equipment is available, conduct an atmospheric analysis before entry into a sealed compartment where oxygen is stowed. Work in teams of two if equipment is not available and entry into a confined space containing oxygen is required. Station one person immediately outside the space while the other is inside.

550-2.11.4 ACETYLENE STOWAGE. To be safe for use, acetylene cylinders must have been in an upright (valve end up) position for the previous 2 hours. If doubt exists as to whether this requirement has been met, do not use the cylinder until it has been in the vertical (valve end up) position for 2 hours. If acetone flows from the cylinder, put aside the cylinder for an additional period.

550-2.11.5 FLAMMABLE AND EXPLOSIVE GAS STOWAGE. In general, weather-deck stowage will be provided for flammable and explosive gases (see paragraph 550-2.11.6). However, in specific cases, depending on the particular type, mission, and arrangement of the ship, below-deck stowage is approved. In such cases, these approved locations are shown on the ship plans.

550-2.11.6 WEATHER DECK STOWAGE. Whenever compressed gases are stowed on the weather deck, observe the following precautions:

1. Do not stow oxygen cylinders in close proximity to fuel gas cylinders.

2. Stow cylinders containing compressed gases so that they will be protected insofar as practical. During winter, protect cylinder valves against accumulation of snow and ice. Use warm (not hot) water to thaw ice accumulations in cylinder valve caps and outlets. During summer, screen cylinders from direct rays of the sun. Make

every effort to prevent corrosion of threaded connections of cylinders in stowage for extended time periods. Do not permit the use of grease or flammable corrosion inhibitors on oxygen cylinders.

3. Ensure that the stowage area is as remote as practical from navigating, fire control, and gun stations.
4. Keep flammable materials, especially grease and oil, out of the stowage area.
5. Securely fasten each individual cylinder in the vertical position (valve end up) by means such as metal collars.

550-2.12 READY SERVICE

550-2.12.1 GENERAL. The term ready service refers to articles that have been transferred from stowage and are physically located in a shop or elsewhere. These articles may or may not be in actual use. Ready service also refers to articles that are being held in reserve in the interim between periods of actual use or in anticipation of a need for immediate use.

550-2.12.1.1 Gas cylinders in use or cylinders ready for use (e.g., attached to welding, firefighting, medical, or refrigerant apparatus) are permitted below decks outside of the stowage compartment (paragraph 550-2.11). Treat disposable cylinders supplied as repair kit accessories (e.g., a halide leak-detector kit) as ready service cylinders. Store kits in a well-ventilated space, preferably above the main deck, when not in use. (See paragraphs 550-2.11.2 and 550-2.11.5.)

550-2.12.2 WELDING CYLINDERS. The following special instructions and precautions regarding oxygen and fuel gas cylinders in ready service for welding shall be followed.

a. Use approved plans or specifications for each shop to determine the number of gas cutting and welding stations authorized. Cylinders of gas necessary to equip each authorized station may be installed in the shop.
b. Securely fasten cylinders in a rack (stationary or wheeled). In turn, securely fasten rack to the bulkhead at the designated location.
c. Keep cylinders attached to, and spare cylinders for, damage-control equipment in repair lockers below decks, if desired.
d. Remove welding units from the designated stowage as necessary to perform work at some remote location in the ship. Return units to the designated stowage immediately upon completion of work. Do not leave equipment unattended while it is away from its regular stowage.
e. When preparing welding units to perform work, back off on the regulator screws, and then open the cylinder valves slowly. Open the acetylene valve one-fourth to one-half turn. This will allow an adequate flow of acetylene, and will still allow the valve to be turned off quickly in an emergency.

WARNING

Never open the acetylene cylinder valve more than one and one-half turns.

The oxygen cylinder valve should be opened all the way to eliminate leakage around the stem.

f. Post a card with the following warning at the designated stowage location of each unit:

WARNING

Unit is NOT SECURE while pressure shows on gages, or when cylinders are not firmly fastened to rack or to bulkhead, or when rack is not firmly fastened to bulkhead. If removed from this location, this unit is to be constantly attended until returned and secured.

g. Attach to each unit a card with the following instructions: Return to (designated location) immediately on completion of work. Unit shall **NOT** be left unattended while away from above location. Unit is NOT SECURE while pressure shows on gages, or cylinders are not firmly fastened to rack, or rack is not firmly fastened to bulkhead or stanchion.

550-2.12.2.1 For additional precautions pertaining to oxygen and fuel gas for welding, see **NSTM Chapter 074, Volume 1, Welding and Allied Processes** , and applicable sections of this chapter.

550-2.12.3 FIRE EXTINGUISHERS. The following fire-extinguishing equipment may be stored in the vicinity in which it is to be used.

a. Fire extinguishers using gases

b. Fire-extinguishing cylinders permanently connected to fixed fire-extinguishing systems

c. Gas and chemical canisters for oxygen- breathing apparatus

550-2.13 SHIP-TYPE CYLINDERS

550-2.13.1 Nonshatterable-type cylinders for high- pressure gases are standard for shipboard use and stores. Shatterable-type cylinders may be used only in the event of an emergency or when nonshatterable cylinders for a given gas are not in Navy stores. In such cases, the shatterable type cylinders shall be turned in as soon as possible to the nearest naval supply depot in exchange for nonshatterable cylinders.

550-2.14 DISPOSITION OF UNSERVICEABLE EMPTY CYLINDERS

550-2.14.1 CYLINDERS OTHER THAN ACETYLENE. After the gas has been removed from any unserviceable cylinder other than an acetylene cylinder, first purge the cylinder if it previously contained a flammable or toxic gas (see paragraph 550-2.8.3). Destroy the empty cylinder with a cutting torch or by other appropriate means, making it unusable as a pressure vessel. It is recommended that the DOT markings on the cylinder be cut out with a torch and that the remainder of the cylinder be cut into two or more pieces.

550-2.14.2 ACETYLENE CYLINDERS. Cylinders marked ICC8, DOT8, ICC8AL, or DOT8AL are authorized for acetylene only. These cylinders are filled with a porous mass that serves as an absorbent for the solvent (acetone) that is used to retain acetylene in solution. An unserviceable acetylene cylinder, therefore, may retain varying quantities of solvent and gas. Before attempting to destroy an acetylene cylinder, ensure that the cylinder is totally discharged. Have the cylinder deenergized as follows by qualified personnel completely familiar with these cylinders:

1. Remove the cylinder to an isolated location where escaping gas will present no hazard to personnel or property.
2. Open the cylinder valve and allow the valve to remain open for at least 24 hours to permit the discharge of residual acetylene.
3. Remove the cylinder valve very carefully, making sure that all gas pressure has been released before completely unscrewing the valve. Perform this operation with caution. If the valve is clogged, there is the danger that the unreleased air may remain in the cylinder.
4. Remove all safety devices from the cylinder. There may be safety devices in both ends of the cylinder.

WARNING

Perform this operation in a location remote from any building or from any place where people may work or assemble.

5. Place the cylinder in a horizontal position. If there is more than one cylinder, place cylinders in stacks one cylinder wide and no more than five cylinders high. Place wood or other fuel around the cylinders and ignite. Keep the cylinders in an intense fire for at least 6 hours.
6. After the cylinders have been in the fire 6 hours, apply a flame to each valve spud. This will ignite any acetone vapors that may issue from the opening. This can be readily done by using a lighted cutting torch.
7. Using a cutting torch, cut out the valve spud and all identification markings on the head of the cylinder. Markings to be cut out include the registered symbol and serial number.
8. Using a cutting torch, make a circumferential cut midway in the cylinder; crack the filler and break the cylinder in half.
9. Allow the cylinder halves to lie until acetone vapors no longer burn.
10. Never store a scrapped cylinder in a confined place.

550-2.15 DISPOSITION OF CHARGED CYLINDERS THAT CANNOT BE DEPRESSURIZED

550-2.15.1 It may sometimes be necessary to dispose of a cylinder that cannot be safety depressurized. In this case, disposition must be made in such a manner that there is no present or future hazard to life or property. If the cylinder and contents are sufficiently heavy to ensure the sinking of the cylinder, the cylinder may be dumped into a large body of deep water. As an alternative, the cylinder may be buried in an appropriate place at a depth sufficient to ensure that it can do no harm to persons or property.

550-2.16 DISPOSITION OF SERVICEABLE EMPTY CYLINDERS

550-2.16.1 GENERAL DISPOSITION. Deliver empty serviceable cylinders to the nearest naval supply depot. Ensure that valves are closed and cylinders are under some positive pressure, unless the valve design does not permit closing (e.g., as in the case of fire extinguishers). Closed valves and internal pressure are necessary to prevent condensation of atmospheric moisture on internal cylinder walls. In the case of acetylene cylinders, closed, slightly pressurized valves are also necessary to prevent loss of the solvent (acetone) and the entry of air should cool the cylinders considerably below discharge temperature.

550-2.16.2 DRY GAS CYLINDER DISPOSITION. It is especially important that cylinders used for aviators' breathing oxygen, dry nitrogen, dry argon, dry helium, or dry air have closed valves and be under some positive pressure. Tag any such cylinder that is found to have an open valve or a positive internal pressure lower than 25 lb/in^2 g. State on the tag that the cylinder must be dried before refilling.

550-2.17 RECHARGING CYLINDERS ABOARD SHIP

550-2.17.1 Certain ship classes (CV and AS) are equipped with oxygen and nitrogen generating plants for supplying shipboard systems. Ships so equipped are authorized to recharge portable oxygen and nitrogen cylinders. Observe the following safety precautions and requirements in this operation:

a. Process only oxygen and nitrogen cylinders, as appropriate.

b. Ensure that the recharging is supervised by a graduate of the Fleet Training Center, Cryogenics School.

c. Do not recharge any cylinder if more than 5 years have passed since its last hydrostatic test date. The only exceptions are 3A and 3AA cylinders having water capacities under 125 pounds for which a 10-year hydrostatic test frequency is approved. (See the **Code of Federal Regulations, title 49, section 173.34(e)1.5** .)

d. If there is evidence of oil or grease above the neck ring, do not recharge oxygen cylinders.

e. Before recharging, sniff test each cylinder for evidence of contamination by a foreign gas. Oxygen and oil-free nitrogen cylinders should be odorless. An oily odor from these cylinders indicates hydrocarbon contamination. Do not recharge contaminated cylinders.

f. Keep shipboard oxygen cylinders (aviators' breathing oxygen) and nitrogen cylinders dry by not allowing the cylinder pressure to go below 25 lb/in^2 g. Consider a cylinder wet if there is insufficient internal pressure to cause a hissing noise when the valve is opened. Return wet cylinders to the supply system. If a shortage of oxygen cylinders develops, use properly marked wet cylinders locally, if necessary, for welding, cutting, and medical purposes. Properly marked cylinders are those that carry adequate (but temporary) warnings that they are not to be used for aviation breathing. At the first opportunity, exchange these wet cylinders for dry cylinders.

550-2.17.2 For additional information on the inspection and maintenance of compressed gas cylinders, see MIL-STD-1411.

550-2.18 NONMAGNETIC CYLINDERS

550-2.18.1 Certain classes of minesweepers must use special nonmagnetic carbon dioxide fire extinguishers. These cylinders are supplied in the 15- and 50-pound sizes and appear similar to standard cylinders. Fabricated of welded stainless steel, they do not comply with DOT3AA construction specifications and are not authorized to be transported by common carrier when charged. Because the cost of these cylinders is high (10 times that of the standard cylinder), a rotating supply is not practical. It is necessary for each ship supplied with nonmagnetic cylinders to see that cylinders are returned after recharging. Retest nonmagnetic cylinders once every 5 years following methods prescribed for DOT cylinders. For the use of nonmagnetic cylinders in scuba diving, see NAVSEA 0994-LP-001-9010 and -9020, **U.S. Navy Diving Manual** , Volumes 1 and 2.

550-2.19 GENERAL SAFETY RULES FOR COMPRESSED GAS CYLINDERS AND GASES

550-2.19.1 Compressed gas cylinders are designed to be safe for the purpose for which they are intended. Serious accidents connected with their handling, use, and stowage almost invariably can be traced to abuse or misuse.

550-2.19.2 The following rules are based upon accident prevention experience. Strictly observe these rules when handling compressed gases. Do not assume, however, that every necessary safety procedure is covered by these rules. Make due allowance for hazards that may be peculiar or accidental to local handling conditions, stowage, and use. Whenever such conditional hazards are met or noted in the course of operations, report them to NAVSEA for dissemination to other commands.

a. Never drop cylinders, nor permit them to strike each other violently.

b. Never use a lifting magnet, or a sling (line or chain) when handling cylinders. If a crane or hoist is used, provide a safe cradle or platform to hold the cylinders.

c. When returning empty cylinders, be sure that valves are closed and that valve outlet and cylinder valve protection caps, if provided, are in place.

d. Be sure that all cylinders in ship's stores are approved under DOT regulations. Nonmagnetic cylinders are an exception.

e. Do not refill cylinders unless such action is specifically approved by the Command concerned and then only in accordance with instructions given in paragraph 550-2.17.

f. Do not fill any cylinder with a gas other than that gas for which the cylinder has been specifically designated. Fill cylinders only as directed in paragraph 550-2.19.2.e. Explosive mixtures may readily be formed when cylinders containing residual combustible gases such as hydrogen, propane, or acetylene are charged with air or oxygen. Charging air or oxygen cylinders with combustible gases is equally hazardous. The mixing of helium and oxygen is an approved exception to the above (see NAVSEA 0994-LP-001-9010 and -9020, **U.S. Navy Diving Manual, Volumes 1 and 2**).

g. Do not remove or change the numbers or marks stamped into cylinders without the specific approval of the Defense General Supply Center.

h. Never use cylinders for rollers, supports, or for any purpose other than to carry gas.

i. Do not tamper with the safety devices on valves or cylinders.

j. Never hammer or strike the valve wheel in attempting to open or close valves. Use only wrenches or tools provided and approved for this purpose.

k. Be sure that the threads of regulators or other auxiliary equipment are the same as those on cylinder valve outlets. Never force connections that do not fit.

l. Do not use regulators, pressure gages, manifolds, and related equipment that are provided for a particular gas on cylinders containing different gases.

m. Do not repair or alter cylinders or valves except when authorized by the Naval Sea Systems Command (NAVSEA).

n. Do not subject compressed gas cylinders, either in stowage or in service, to a temperature in excess of 54.4°C (130°F). A direct flame should never be permitted to come in contact with any part of a compressed gas cylinder.

o. Protect cylinders from objects that will cut or otherwise abrade the surface of the metal.

p. When testing for leaking gas cylinders, use soapy water or leak-detection compound conforming to MIL-L-25567.

Type I, 4 ounce - NSN 6850-00621-1820

Type 1, 1 quart - NSN 6850-00621-1819

Type II, 4 ounce - NSN 6850-00621-1819 Conduct tests well clear of open flames and other sources of potential ignition, such as unshielded lamps or switches.

q. Do not use any gas cylinder that is improperly marked (by color of paints or with name of gas stenciled on cylinder and valve). Return all mismarked cylinders to the nearest naval supply depot.

r. Keep compartments where compressed gases are stored (or in use) well ventilated.

s. To thaw out valve outlets that are clogged with ice, use warm (not boiling) water. The use of boiling water will melt the fusible plugs (if present) and vent the cylinders.

t. Never discharge a cylinder into any device or equipment in which the gas will be entrapped and create pressure. The only exception is a cylinder equipped with a pressure regulator set to control the pressure.

u. Never use oil-tolerant gases when oil-free gases are required. This practice is discouraged by the fact that valve outlets are not interchangeable. However, there have been cases in which this safety feature has been overcome by homemade adapters.

SECTION 3.

CRYOGENIC LIQUID STORAGE

550-3.1 GENERAL

550-3.1.1 Oxygen and nitrogen are the only gases under NAVSEA cognizance that are stored aboard ship as low-temperature (cryogenic) liquids at essentially atmospheric pressure. Because of their extremely low temperatures, specially insulated storage containers and liquid transfer lines are used. These special containers and lines minimize the flow of heat into the liquids from the surrounding atmosphere. The liquids are at their boiling points (-183°C (-297.5°F) for oxygen; -196°C, (-320°F) for nitrogen). Therefore, each unit of heat absorbed results in the evaporation of a fixed quantity of liquid from the system. The loss can be recovered only by supplying additional refrigeration to effect recondensation. Accordingly, the rate of evaporation of a particular liquid is a practical measure of a tank's insulation effectiveness.

550-3.1.2 Despite the evaporation losses associated with the storage of liquid oxygen and liquid nitrogen, this type of storage is preferred to compressed gas storage. Liquid storage offers considerable savings in both weight and volume of equipment, as shown in Table 550-3-1.

550-3.2 APPLICABILITY

550-3.2.1 Liquid oxygen and liquid nitrogen storage tanks are usually installed aboard Navy ships in conjunction with and connected to appropriate liquid oxygen-nitrogen plants (see Section 5). Such tanks are built in a variety of shapes. They range in size from 30 to 1,500 gallons, depending on the rate of liquid production and usage. Among the ships equipped with liquid oxygen and liquid nitrogen are aircraft carriers and submarine tenders. The liquid oxygen eventually is converted to a gas and used for aviators' breathing and for replenishing submarine atmosphere. Liquid nitrogen may be used directly, in the liquid state, for instrument cooling. After

vaporization nitrogen may be used for various applications requiring an inert gas. Among its uses is that of a purge gas for electrolytic oxygen generators (see Section 5).

550-3.3 TANK DESIGN

550-3.3.1 All shipboard liquefied gas tanks have double walls and contain insulating powder under vacuum (usually fewer than 100 micrometers of pressure) in the annular spaces. The insulating space is usually at least 4 inches thick at all points on the tank. Typical insulating powders used in shipboard installations are perlite and silica aerogel, often referred to by its trade name, Santocel. The purpose of the evacuated annular space is to reduce heat conduction from the atmosphere to the liquid contents of the tank. The fine powder is added to reduce radiant heat transfer from the warmer to the colder surfaces, particularly where these surfaces are not highly reflective.

Table 550-3-1. COMPARISON OF LIQUID AND GASEOUS OXYGEN-NITROGEN STORAGE SYSTEMS

System	Pressure	Weight of Oxygen (Pounds)	Weight of Nitrogen (Pounds)	Weight of Equipment (Pounds)	Volume of Equipment (Cubic Feet)
Liquid	1 atm	14,280*	10,118*	14,000	700
Gas	3000 lb/in^2 g	14,280	10,118	75,000	1,400

*Represents 1,500 gallons of liquid.

550-3.3.2 Good tank design requires that there be few short-circuiting, heat-conducting paths between the inner and outer walls. Such paths are furnished by the inner vessel supports and by internal piping. For this reason, tank supports usually consist of a few long, narrow rods of a low-heat-conductance metal, such as stainless steel. Internal piping that bridges the warm and cold walls is also of extended length (especially liquid-carrying lines) and of stainless steel. Dimensional changes in the piping often are provided for by metal bellows sections.

550-3.3.3 A photograph and a schematic representation of a typical shipboard cylindrical storage tank for low-temperature liquids are given in Figure 550-3-1 and Figure 550-3-2 respectively. All piping and various items of supplementary equipment that may be required are shown. To prevent the buildup of dangerously high pressure through the evaporation of the stored liquid, the inner tank (usually of corrosion-resistant stainless steel) is vented overboard through a back pressure regulator set at some low positive pressure (5 to 15 lb/in^2 g). This pressure permits adequate priming of any liquid pumps that may be connected to the system (see Section 4). If required, higher tank pressure may be slowly developed by resetting the pressure regulator and allowing normal evaporation to take place. Or higher tank pressure may be more rapidly developed by means of the pressure-building coil. This coil, which is uninsulated and exposed to normal room temperatures, rapidly vaporizes liquid that is fed to it through the pressure-building valve. A relief valve and a rupture disk protect the tank against excessive pressures. The relief valve may be set at 30 to 55 lb/in^2 g; the rupture disk is designed for somewhat higher pressure. Very rapid pressurization of the tank for emergency overboard discharge of the liquid contents is possible. Simply admit 25 to 50 lb/in^2 g oxygen or nitrogen gas, as applicable, from an external source through the emergency pressure buildup line.

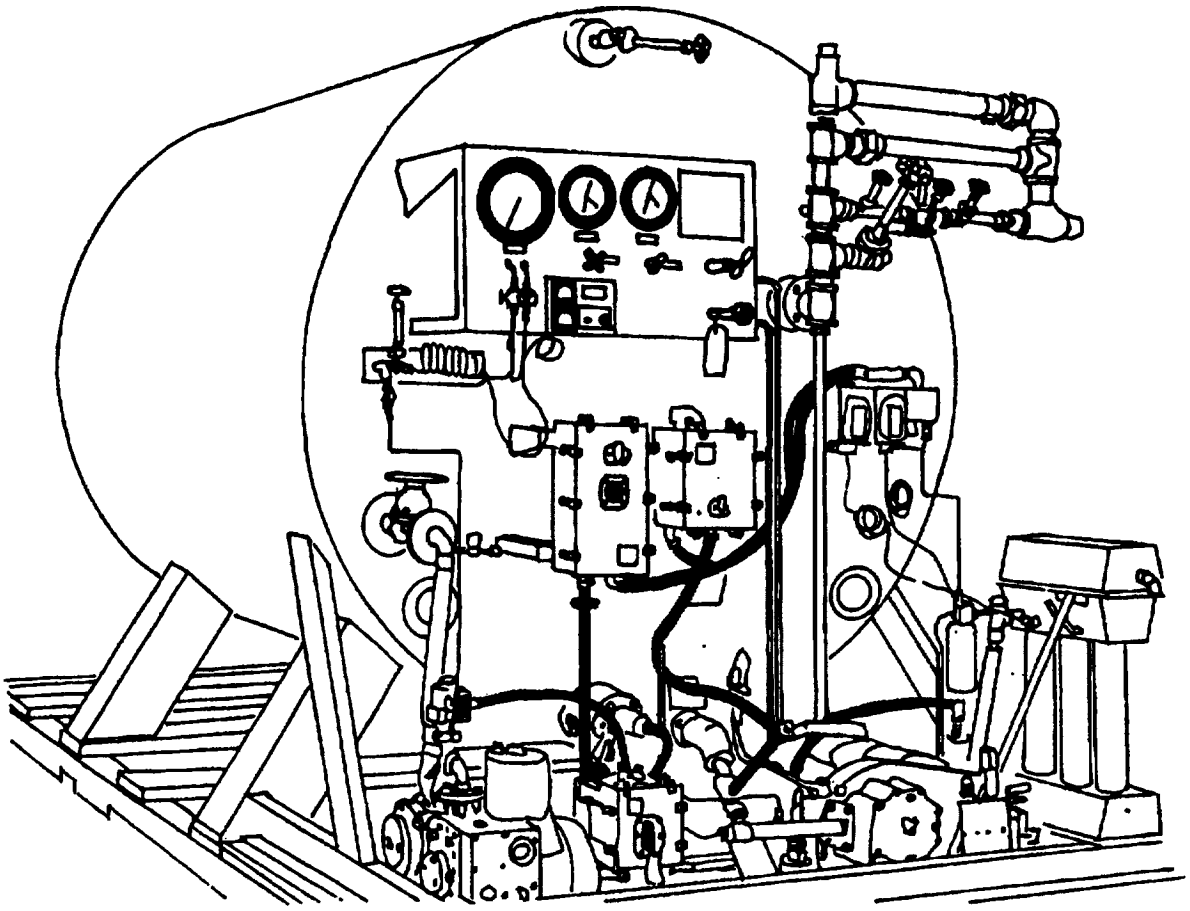

Figure 550-3-1. Shipboard 1,500-Gallon Liquid Oxygen Tank

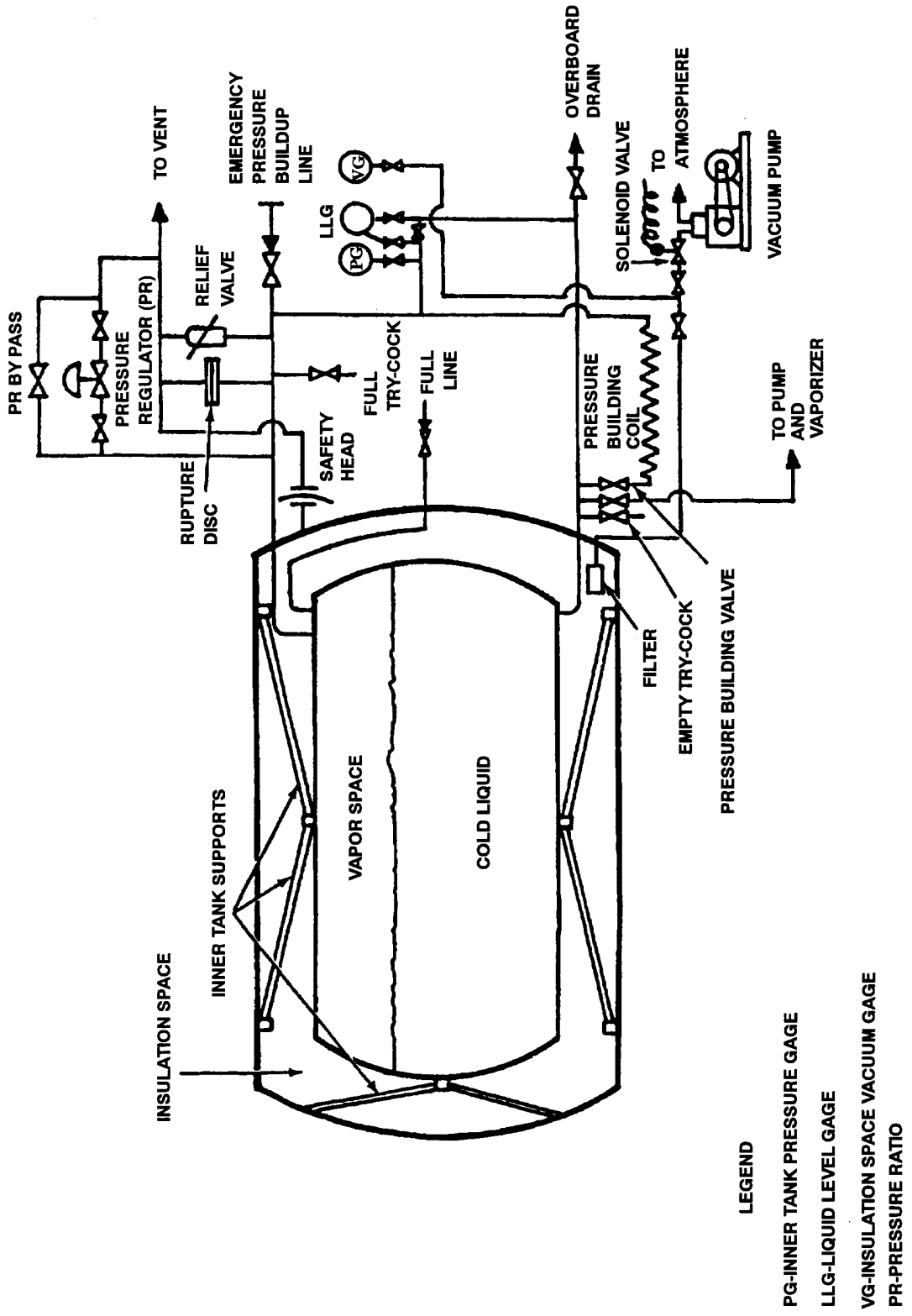

Figure 550-3-2. Schematic of a Liquid Oxygen or Liquid Nitrogen Storage Tank

550-3.3.4 The inner tank is normally designed to withstand pressures in excess of 30-50 lb/in^2 g when surrounded by high vacuum. However, it is vulnerable to relatively small pressure differentials in the reverse direction. That is, the tank may collapse if its internal pressure is atmospheric and the annular space pressure is only slightly higher. This may occur if a small leak in the inner tank allows cold liquid to enter the warmer annular space. Evaporation of the leaking liquid may cause a rapid pressure buildup that cannot be compensated for by the vacuum pump. To protect against this contingency, either a spring loaded safety head or a rupture disk is usually provided in the outer shell. The safety head or rupture disk is adjusted to relieve at pressures of about 1 to 5 lb/in^2 g.

550-3.4 VACUUM SYSTEM

550-3.4.1 Most shipboard tanks are furnished with a two-stage mechanical vacuum pump to maintain an adequate vacuum in the annular insulation space. Gas is pumped from this space through a permanently installed filter to prevent insulating powder from entering the vacuum pump. The pump should be capable, at all times, of maintaining a maximum pressure of fewer than 20 micrometers (0.02 millimeters of mercury column pressure) under dead-end conditions. For liquid oxygen containers, a fire resistant vacuum pump lubricant such as tricresylphosphate must be used. This type of lubricant minimizes the danger of fire resulting when vaporized oxygen gas leaking into the annular space comes into close contact with the lubricant.

550-3.4.2 The suction line between the tank and the vacuum pump is usually equipped with one or more hand operated shutoff valves. These valves permit selective measurement of either tank or dead-end vacuum. The suction line may also have a solenoid valve. The solenoid valve closes when the pump motor is turned off to prevent back leakage through the pump. Because frictional losses are reflected in a correspondingly poorer vacuum, the suction line should be of large diameter and as short as possible to minimize these losses during vacuum pump operation. Evaporation losses for a hypothetical liquid oxygen storage tank are shown in Figure 550-3-3.

550-3.5 PRESSURE GAGES

550-3.5.1 GENERAL. Liquid oxygen and nitrogen storage tanks have three pressure gages: the inner tank gage, the liquid level gage, and the insulation space vacuum gage (see Figure 550-3-2).

550-3.5.2 INNER TANK GAGE. The inner tank gage is a low-pressure gage of the Bourdon-tube type, connected to the vapor space above the liquid. The normal reading may vary from 0 to 15 lb/in^2 g, reflecting the setting of the pressure regulator.

550-3.5.3 LIQUID LEVEL GAGE. This is usually a bellows type differential pressure gage. One leg of this gage communicates with the inner tank vapor space; the other, with the liquid drain line. The gage is usually calibrated in gallons of liquid oxygen or liquid nitrogen. Because of its sensitivity, it may be provided with a bypass valve to protect it from surges resulting from rapid pressure changes.

NOTE

The full and empty try-cocks may be used as very rough liquid-level indicators during tank filling and draining operations.

550-3.5.4 VACUUM GAGE. Two different types of gages are used to measure the vacuum in the insulation spaces of shipboard storage tanks. These gages are the McLeod gage and the thermocouple gage.

550-3.5.4.1 McLeod Gage. The McLeod gage is probably the most widely used vacuum gage and, when properly maintained and calibrated, the most satisfactory. It is an absolute pressure gage. A sample of the gas is trapped in a fixed volume and compressed by mercury to a much smaller volume in a glass capillary tube. The final volume may be accurately read and, by calibration, converted to the initial gas pressure.

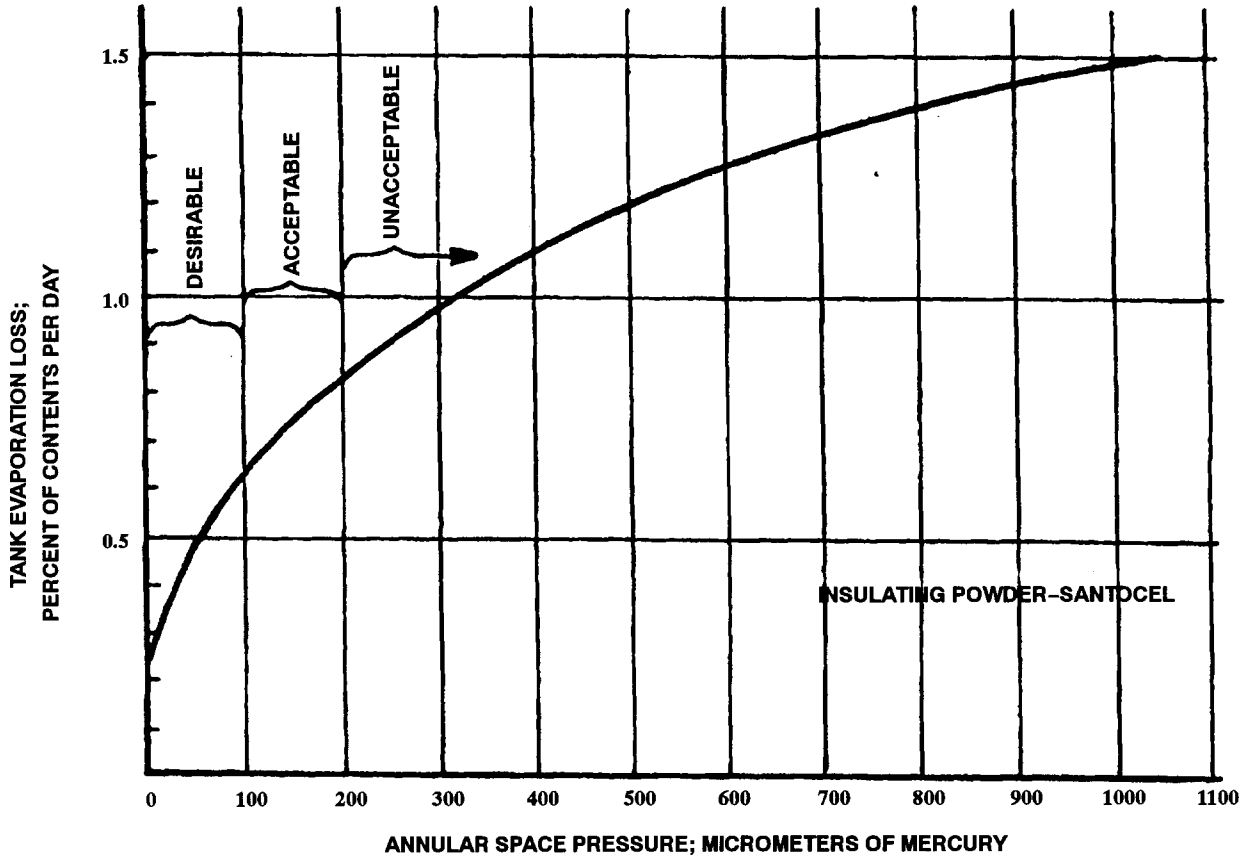

Figure 550-3-3. Effect of Insulating Vacuum on Evaporation Rate of Liquid Oxygen from Hypothetical Tank

550-3.5.4.2 Thermocouple Gage. In this gage the junction of a thermocouple is in thermal contact with a small resistance heater. The assembly is mounted in a tube that communicates with the vacuum to be measured. This junction is cooled by the gas under vacuum, the degree of cooling being a function of the absolute pressure. The voltage generated by the thermocouple may be read on a micrometer in a closed electrical circuit and calibrated in terms of pressure

550-3.6 LIQUID TRANSFER LINES

550-3.6.1 Shipboard liquid oxygen and liquid nitrogen storage tanks are usually supplied from liquid oxygen or liquid nitrogen plants at relatively low flow rates. Depending upon the size of the plant, the flow rate varies from 11 to 21 gallons per hour for oxygen and from 15 to 29 gallons per hour for nitrogen. In almost every case, the liquid leaving the plant is subcooled to slightly below its normal (atmospheric-pressure) boiling point; nevertheless, great care must be taken to prevent excessive losses by evaporation. Such evaporation may occur within the transfer line as a result of heat leaking from the atmosphere. Similarly, when liquid from the tank is pumped to a higher pressure prior to vaporization and storage as a gas (see Section 4), it is important to take several precautions. Vapor binding of the pump may result from excessive boiloff in the suction line. To prevent excessive

evaporation, shipboard low-temperature liquid transfer lines are well insulated. Either a porous, low-conductive medium (e.g., powder, glasswool, foam) or an evacuated powder similar to that used in the storage tank is used.

550-3.6.2 If a nonevacuated insulating medium is used, an external vapor barrier is installed (e.g., the barrier may be a large diameter pipe, a sheet metal enclosure, plastic-coated fabric, or fabric coated with vapor barrier paint or paste). The barrier will prevent atmospheric moisture from entering the insulation space and condensing on the cold transfer line, resulting in loss of insulating efficiency. This method of insulation, while not the most effective, is the simplest and least expensive. It is usually satisfactory for short lines carrying liquid at relatively high flow rates. Rigid, vacuum-insulated piping, on the other hand, must be designed to permit differential expansion of the inner and outer tubes. This may be done with flexible bellows in either the inner or outer piping, or in both.

550-3.6.3 Evacuated powder-insulated lines are provided with spacers or supports made from poor conducting materials such as Teflon. These spacers or supports separate the cold inner pipe from the outer piping. They are designed so that they have the least possible thermal contact with the inner and outer pipe, thereby minimizing head conduction between these pipes. A section of well-designed delivery tubing connected to the inlet line of a liquefied gas storage tank is shown in Figure 550-3-4.

550-3.7 MAINTENANCE OF VACUUM LEVELS

550-3.7.1 GENERAL. Vacuum levels in stabilized liquid oxygen and liquid nitrogen storage tanks and transfer lines are evaluated as follows:

- Below 100 micrometers - Desirable
- 100-200 micrometers - Not desirable but acceptable
- Above 200 micrometers - Unacceptable

550-3.7.1.1 Do not permit the vacuum level to rise much above 100 micrometers. The ratio of boiloff to vacuum level is not linear; significant savings will result if the vacuum is held well below 100 micrometers.

550-3.7.1.2 With regard to maintaining vacuum levels in all shipboard liquid oxygen and liquid nitrogen systems, comply with the guidelines presented in paragraphs 550-3.7.2 through 550-3.7.7.

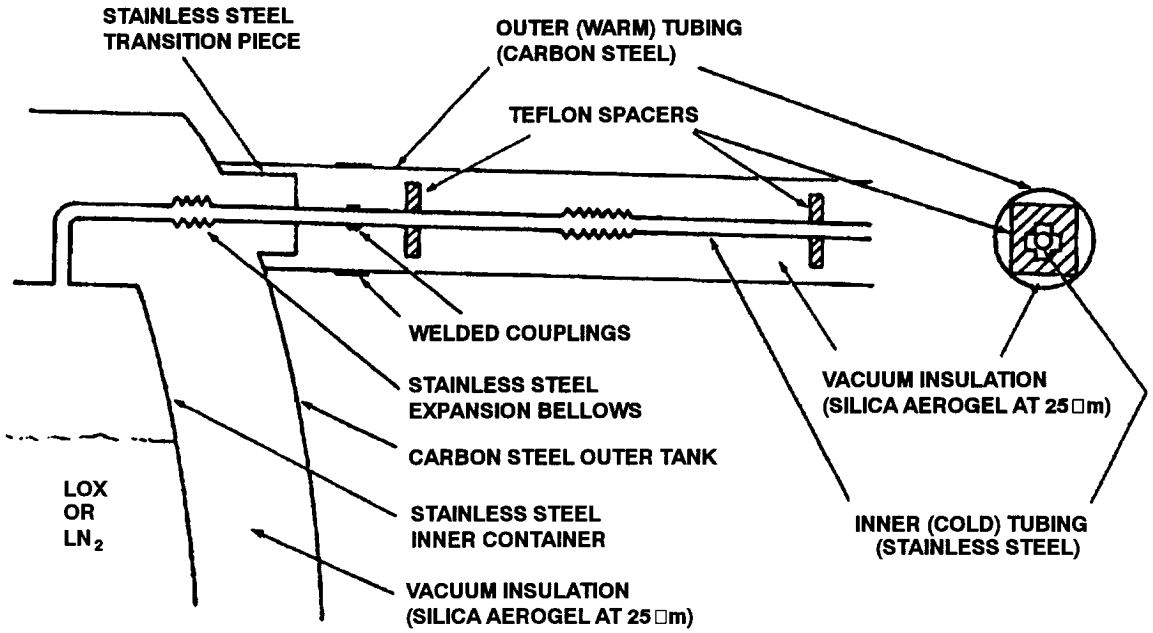

Figure 550-3-4. Typical Vacuum-Installation Delivery Line and Tank

550-3.7.2 KEEPING VACUUM PUMP LUBRICANT DRY. Many lubricants, especially tricresyl phosphate, readily absorb water vapor, impairing the capability of the pump to attain the required vacuum. The vacuum loss results because lubricant contaminated with moisture exerts more vapor pressure than does lubricant that is pure and dry. Observe the following operating procedures and precautions in order to avoid oil contamination and ensure good operational characteristics:

1. Prior to startup, purge the oil in the pump reservoir to remove any moisture present. Do this by bubbling dry, ambient-temperature nitrogen through the lubricant by way of the drain plug.

2. Purge the oil during tank pump-down. Connect a line to the oil separator drain; slowly and continuously bubble dry, ambient-temperature nitrogen gas through the lubricant. The nitrogen flow rate should not be so great as to carry lubricant over into the pump exhaust line. Purging during operation will prevent water vapor that was previously absorbed by the tank insulation material from being absorbed by the lubricant.

3. Replace the vacuum-pump lubricant frequently. Change lubricant every 200 hours. Change the lubricant even sooner if there is any visible evidence of excessive contamination.

550-3.7.3 VACUUM PUMP MAINTENANCE. Remember that vacuum pumps are precision devices and must be treated with care to obtain proper performance. Pumps can be tested by using a McLeod-type gage to measure the base or dead end pressure that the isolated pump will produce. The base pressure varies somewhat with different pumps but usually ranges from 5 to 20 micrometers of mercury depending on the lubricant used. A base pressure higher than this indicates either that the lubricant is contaminated or that there is a mechanical malfunction. Good lubrication is essential. Change oil frequently to prevent destruction of the oil by oxidation and the deposit of gum residue on pump surfaces.

550-3.7.4 TANK AND PIPING MAINTENANCE. The most common vacuum leaks are those in the tank rupture disks resulting from improper seating or wear. Leaks are also likely to be common at vacuum, fill, vent, drain, and gage connections through the outer shell.

550-3.7.4.1 Observe the following general practices in maintaining a tight vacuum system:

a. Keep surfaces free from dirt or grease.

b. Keep finished surfaces such as flange and valve seats free from scratches and other defects.

c. Clean and treat gaskets and O-rings with a light film of vacuum wax prior to assembly. Use the vacuum wax and application procedure prescribed in the vacuum instruction manual.

d. Seal threaded pipe joints with low-vapor compounds such as General Electric Glyptol 1210 or equivalent.

e. Clamp hose connections.

550-3.7.4.2 One possible cause of an abnormally high liquid oxygen or nitrogen evaporation rate is the packing down of insulation material in the vacuum jacket over a period of time. This can be corrected by breaking the tank insulation space vacuum with dry nitrogen gas and then topping off the space with dry insulation material. An inherent characteristic of insulation material -- which may appear at first to indicate a leak -- is its tendency to absorb moisture. Moisture-laden insulation material means increased vapor pressure. As a result, the vacuum pump is unable to evacuate the tank insulation space to the desired level. The insulation material must be completely dry to obtain good results.

550-3.7.5 PUMP-DOWN OPERATION. Before starting a vacuum pump, always check the oil level. Turn the pump over by hand at least one revolution to make sure there is no binding of moving parts. After checking for operational readiness, start the pump against dead end (with all vacuum valves closed). Allow the pump to run for 10 minutes. A dead-end vacuum of not over 100 micrometers should be obtainable in this length of time. If the inner tank does not contain liquid, proceed with the pump-down procedure as follows:

1. After checking out the vacuum pump as directed above, pump the insulation space of the warm tank down to its minimum obtainable vacuum, preferably under 200 micrometers. The time required for pump-down may vary from several hours to 1 or 2 days, depending on the size tank and vacuum pump involved. When the minimum obtainable vacuum has been reached, shut off the pump and secure the vacuum valves.
2. The tank is now ready to receive liquid oxygen or liquid nitrogen. Introduce liquid into the tank slowly in order to minimize rapid boiling caused by contact with the warm metal. This will prevent loss of liquid by entrainment in the vent gas.

CAUTION

After filling begins, it is possible for the vacuum level to fall below that of the dead-end pressure of the pump. Never attempt to operate a pump in this condition. There is the danger of pulling oil into the insulation space. Be sure that the vacuum valve is closed whenever liquid is admitted to a warm tank. This will isolate the pump from the insulation space.

3. After filling begins, the existing vacuum level in the insulation space will rapidly drop as a result of the sudden low temperature of the inner tank. When conditions have stabilized, the vacuum level in the insulation

space should have dropped to below 100 micrometers. If it has not, apparently a leak has developed. Drain the liquid from the tank and allow it to warm to the ambient temperature. Then proceed to check the tank for leaks.

550-3.7.5.1 Normally it will be necessary to operate the pump only once every few days to maintain the proper vacuum level. When the vacuum rises to 200 micrometers, check and start the pump and reevacuate the insulation space to below 100 micrometers.

550-3.7.6 LEAK DETECTION. Leaks in the outer tank can be located by one of several methods. In all cases, first drain all liquid oxygen or nitrogen and allow tank to warm up to ambient temperature.

550-3.7.6.1 Soap Solution. One method of detecting leaks involves the use of a leak detector solution in accordance with MIL-L-25567. First, pressurize the inner tank to 25 lb/in/^{2} g with oxygen or oil-free nitrogen and the insulation space to 15 lb/in^2 g with dry helium or nitrogen (helium is more effective) by connecting to the tank vacuum pump. Locate the leaks by applying leak detector solution and looking for bubbles. (Outer-shell safety devices, depending upon their settings, may have to be blanked off for such tests.)

CAUTION

Appropriate safety measures shall be exercised when using freon as outlined in NSTM Chapter 516, Refrigeration Systems. To prevent injury, refer to NSTM Chapter 516, Section 1, for safe handling and testing procedures.

550-3.7.6.2 Halogen. As an alternative method of leak detection, pressurize the inner tank with oil-free nitrogen and substitute Freon for helium or nitrogen in the insulation space as in the foregoing procedure. Use a halogen torch to locate the leak. Use a more sensitive electronic halogen leak detector in place of a halogen torch for even better results. An electronic leak detector is also available for use when helium is the pressurizing medium.

WARNING

Acetone is flammable.

550-3.7.6.3 Acetone. Check tanks that have small leaks but that will still permit pumping to below 300 micrometers as follows. Evacuate the insulation space to below 300 micrometers. Station one person to observe the vacuum gage while another person paints suspected areas with acetone. A sharp rise in vacuum pressure will occur within 10-20 seconds after a leak is covered with acetone.

550-3.7.6.4 Exhaust Gas Analysis. To verify leaks in an inner container by the most practical means, pressurize the container to its working pressure with the gas involved. Analyze the exhaust gas of the vacuum pump for increased concentration of that gas.

550-3.7.6.5 Helium. Leaks that cannot be detected with any of the above methods will require a helium leak detector and the services of a trained operator.

550-3.7.7 LEAK REPAIR. Repair of leaks in cryogenic storage tanks is generally not within the capabilities of the ship's force. Leaks should be brought to the attention of the Naval Sea Systems Command (NAVSEA), for appropriate action.

550-3.8 SAFETY PRECAUTIONS

550-3.8.1 Vacuum pumps and all other equipment used in connection with liquid or gaseous oxygen or nitrogen should be treated with proper respect, as outlined herein. High purity oxygen is not unreasonably dangerous as long as the proper care is consistently taken and operational safety precautions listed in oxygen-nitrogen plant and storage tank instruction books are observed. Safety precautions peculiar to vacuum pumps are as follows:

a. Never operate the vacuum pump if it is suspected that an oxygen tank inner container is leaking into the outer shell. The vacuum-pump lubricant may ignite in an atmosphere of high oxygen concentration. If the pump is operating and a leak is suspected, test pump exhaust gases with an Orsat analyzer. If exhaust gases contain more than 25 percent oxygen, shut down pump immediately and report the leak to NAVSEA.

b. Never perform repair work such as welding or soldering or tamper with connections on a tank or system containing liquid or gaseous oxygen. Oxygen-nitrogen equipment should be purged and be at ambient temperature before attempting such repairs.

c. Phosphate ester lubricants, such as Cellulube and tricresyl phosphate, that are used in many vacuum pumps, are toxic. Observe the following safety precautions in operating any equipment that uses such lubricants:
   1. Maintain adequate ventilation if vacuum pump discharge is not piped overboard.
   2. Avoid skin contact. If contact does occur, wash immediately using large quantities of soap and water.
   3. Be careful when shutting down a vacuum pump. Close the vacuum valve before securing the pump even if the pump is designed to prevent a back-flow of oil into the evacuation space.

550-3.9 TANK CONTAMINATION TREATMENT

550-3.9.1 ACETYLENE CONTAMINATION. If two consecutive tests indicate excessive concentrations of acetylene (above 2.0 parts per million by weight) in a liquid oxygen sample drawn from a storage tank, discard the tank contents immediately. Refill the tank with liquid oxygen from the generator. Rerun the acetylene test when the tank is at least three-fourths full (or after 7 days, whichever occurs sooner). If the second test again shows excessive acetylene, drain the tank a second time. Warm the drained tank to room temperature by one of two methods. Either allow it to stand empty or purge it with warm (121°C (250°F)), dry nitrogen gas until the exit gas reaches a temperature of 37.8°C (100°F). The tank may then be refilled with liquid oxygen from the generator.

550-3.9.2 OTHER CONTAMINATION. If infrared spectrophotometer analysis of a liquid oxygen sample indicates nonconformance with prescribed limits, drain and purge the storage tank in accordance with NAVAIRNOTE 10332. As further insurance against undetected accumulation of contaminants in shipboard liquid oxygen tanks, follow the schedule for purging and cleaning given in NAVAIRNOTE 10332.

550-3.9.3 LIQUID OXYGEN AND NITROGEN STORAGE TANK PURGING. This describes purging of liquid oxygen and nitrogen storage tanks when contaminant analysis indicates that the tank is contaminated.

550-3.9.3.1 Liquid oxygen (LOX) storage tanks will require purging when analyses of LOX samples for contaminants indicate that the storage tank contents have become contaminated and dilution with fresh LOX or ″LOX washing″ will not solve the problem. For CV/CVN class ships, the aviators' breathing oxygen (ABO) program, NAVAIR technical manual A6-332A0-GYD-000 (NSN 0817-LP-304-7000) specifies oxygen trace contaminant limits and use limits.

550-3.9.3.2 A liquid storage tank is purged of contaminants by having a warmed gas flow through the inner vessel. The warmed gas will vaporize any contaminants and the gas will sweep the contaminants out of the tank. The purge gas can be dry oil-free waste gas or air from the 0_2 N_2 producer, nitrogen from the ship's nitrogen distribution system, or cylinders of oil-free nitrogen. The storage tank must be drained prior to purging.

550-3.9.3.3 To prepare to purge an oxygen tank, connect a typical large inside diameter (ID) LOX cart fill hose to the oxygen storage tank LOX cart fill connection. This will introduce the purge gas into the bottom of the storage tank. Allow the purge gas to exit at the top of the tank by opening the overboard vent valve on the storage tank vent manifold. If a large ID LOX cart fill hose is not available, use one inch copper tubing and appropriate size fittings to adapt to the tank entry point. Ensure tubing and fittings have been cleaned using trichlorotrifluoroethane (R-113) solvent.

550-3.9.3.4 To prepare to purge a nitrogen tank, connect one inch copper tubing and appropriate size fittings to adapt to the tank entry point or to the liquid nitrogen (LIN) container fill connection (if installed) in the O_2 N_2 Fill Room. Ensure tubing and fittings have been cleaned.

550-3.9.3.5 If the source of purge gas is to be the O_2 N_2 producer, proceed as follows:

a. Air Products LGSB 80-30 series: remove thermometer T-34 and install appropriate size fittings, including a tee, and adapt to hose or copper tubing. Reinstall thermometer T-34 in the tee run and connect the hose/tubing to the tee branch. With the O_2 N_2 producer in operation, align the CO_2 adsorber heater for operation. Set flow rate to the same value as if reactivating the CO_2 adsorber. Energize the heater and monitor flow rate and temperature using instrumentation installed on the O_2 N_2 producer.

b. HP Geeco O_2 N_2 Producers: disconnect reactivation gas heater X2 crossover piping either at the purifier skid or at the cold box skid. Using appropriate size fittings, adapt to and connect hose/tubing to the heater outlet. With the O_2 N_2 producer in operation, align heater X2 for operation. Set flow rate to the same value as if reactivating the crude oxygen purifier. Energize the heater and monitor flow rate and temperature using the instrumentation installed on the O_2 N_2 producer.

c. Cosmodyne GB-2 series O_2 N_2 Producers: remove the cap/plug assembly from the emergency external air source connection downstream of valve TM-4. Using the appropriate size fittings, connect hose/tubing to the emergency air source connection. Place the O_2 N_2 producer in the dry thaw mode of operation and supply warmed gas to the storage tank through valve TM-4.

d. The remaining O_2 N_2 producers (Cosmodyne GB-3 and Geeco J72078) do not have convenient access points to utilize warmed thaw/reactivation gas for purging the storage tanks; therefore ships having these O_2 N_2 producers should use one of the alternatives cited in paragraphs 550-3.9.3.6 or 550-3.9.3.7.

550-3.9.3.6 If nitrogen from the ship's distribution system is to be used for purging the storage tank, proceed as follows:

a. On ships having a HEX Industries superheater installed for purging LOX carts, connect the LOX cart fill hose to the superheater outlet. Align the nitrogen distribution system to establish gas flow through the superheater and then energize the superheater.

b. On those ships that do not have a LOX cart purge heater installed, a convenient access point in the 40/50 psi piping portion of the nitrogen distribution system should be selected. Using the appropriate size fittings, connect copper tubing to the distribution system outlet, install a heater and then connect the heater outlet to the selected storage tank purge inlet. The heater can be as simple as a length of copper tubing that has been coiled and inserted into a small drum filled with hot (steam heated) water. Align the nitrogen distribution system to establish gas flow through the heater.

550-3.9.3.7 If there is an inadequate supply of nitrogen in the ship's nitrogen distribution system, then cylinders of oil-free nitrogen can be used to supply purge gas. A regulator must be installed on each cylinder being used to supply purge gas. The regulator outlet pressure should be set between 5 and 25 psig. Install a heater (see paragraph 550-3.9.3.6 above) to warm the purge gas.

550-3.9.3.8 Align the storage tank valves and start the flow of purge gas. Ensure purge gas outlet valve (tank vent valve) is opened. Monitor the purge gas outlet from the tank, and when it becomes warm to the touch (80°F to 100°F), tank purging is complete. If using an electric heater, secure heater and continue purge gas flow until heater outlet gas temperature has cooled to below 100°F, then stop purge gas flow. Restore storage tank, O_2 N_2 producer, and nitrogen distribution system to its original configuration.

550-3.9.3.9 If desired, the purge gas flow through the tank can be reversed, i.e., in at the top of the tank and out at the bottom.

550-3.9.3.10 Relief valves installed on the O_2 N_2 producer(s), nitrogen distribution system and storage tank(s) will provide protection against system overpressurization.

550-3.9.3.11 Appropriate safety precautions are cited in the applicable O_2 N_2 producer, storage tank, ship specific O_2 N_2 system technical manuals.

550-3.10 PREVENTIVE MAINTENANCE

550-3.10.1 If the Planned Maintenance System (PMS) is installed, conduct cryogenic liquid storage preventive maintenance in accordance with Maintenance Requirement Cards (MRC's).

SECTION 4.

CRYOGENIC CHARGING SYSTEMS

550-4.1 GENERAL

550-4.1.1 Almost all shipboard-produced and stored liquid oxygen and liquid nitrogen are converted to the gaseous state before use (see paragraph 550-3.2.1). In modern plants, positive displacement pumps, operating directly upon the high-density liquid, force it through a heat exchanger. Here it is vaporized under high pressure

(3,000 or more lb/in^2 g) and then delivered to high-pressure storage flasks. The conversion method is economical in the use of power and does not introduce contaminants, such as lubricating oil or water, into the gaseous product.

550-4.2 CRYOGENIC PUMPS

550-4.2.1 GENERAL. Liquid oxygen and liquid nitrogen are converted into the gaseous state by pumps that operate on the principles of cryogenics. Cryogenics is the science that deals with the production of very low temperatures and the effect of these temperatures on matter. A single-cylinder, positive-displacement, reciprocating cryogenic pump that has proven very effective in high-pressure charging service is shown in Figure 550-4-1.

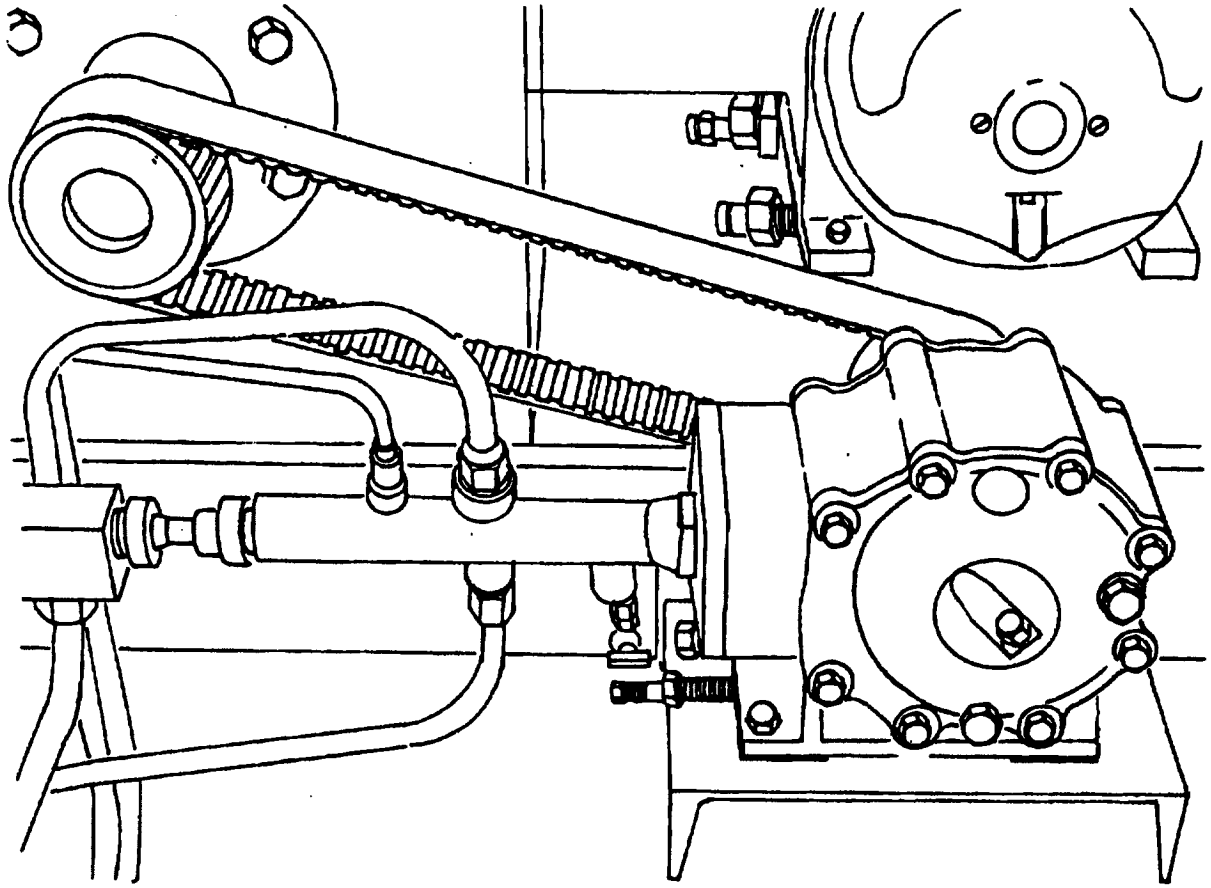

Figure 550-4-1. High-Pressure Liquid Oxygen Pump

550-4.2.2 DESIGN. A one-piece push rod connected to a conventional crosshead, connecting rod, and crankshaft assembly drives the pump piston. Spherical roller bearings support the crankshaft. A single spherical roller bearing supports the connecting rod on the crankshaft. A wet-sump splash system lubricates the bearings, crankshaft, and crosshead. The pump has two sections. The first section is the drive or warm end, which contains the crankshaft, connecting rod, crosshead, and bearings and which can operate over a temperature range of 18°C (65°F) to 80°C (175°F). The second section is the cylinder housing or cold end, which contains the piston, cylinder, valves, push rod, and oil packings. In addition, there is a region for separating the warm and cold ends in order to prevent heat leakage. The design of the drive end allows the input shaft to be extended from either side.

550-4.2.3 THERMAL ISOLATION. There is a large temperature difference between the cold and warm ends of the pump. A good heat transfer barrier is necessary to maintain cold-end temperatures compatible with the cryogenic fluid. The barrier eliminates cavitation during the heating of liquid in the inlet chamber and in the high-pressure cylinder. The violent collapse of gas bubbles formed in the cryogenic fluid during pump operation causes cavitation. Heat leakage is minimized by making the push rod and the cylinder housing relatively long, with a small cross-sectional area. A dead-gas space in the center of the cylinder housing allows for proper operation of end oil seals and of the lubricated drive shaft.

550-4.2.4 OPERATION. The operation of a typical cryogenic pump found on naval ships is described in paragraphs 550-4.2.4.1 and 550-4.2.4.2. For information on individual ship installations, consult the specific pump technical manual.

550-4.2.4.1 Before the pump is started, its cold end is cooled down to cryogenic liquid temperature by the fluid flowing through the high- and low-pressure ports in the pump cold end. The pump is then actuated by starting the drive motor. The fluid under low pressure in the inlet chamber is admitted into the cylinder on the return stroke of the piston. The fluid enters the cylinder through an annular space formed by the hollow piston and the inlet valve that fits inside the piston (see Figure 550-4-2A).The piston is then driven by the inlet-valve push rod on its compression stroke (see Figure 550-4-2B). During this time the liquid is raised to pressure and delivered through the spring-loaded discharge valve to the high-pressure system (see Figure 550-4-2C). On the return stroke, the inlet valve is unseated from the piston. This opens the passage between the cylinder and the inlet chamber. As the inlet valve retracts 0.1 to 0.2 inches, the retractor pin in the piston is engaged by the push rod, and the piston is returned to bottom dead center. As this happens, a new charge of fluid flows through the opened inlet passage as described previously. The inlet-valve push rod again seats in the piston and the cycle is completed.

550-4.2.4.2 The crosshead, connecting rod, and crankshaft assembly actuates the inlet valve push rod. A warm-end and cold-end assembly supports the push rod. This assembly consists of a bushing to take push rod side loads and two series of chevron packings to seal the lubricated drive assembly from the cold end. Also included in the assembly are springs to supply a sufficient loading on the chevron packings to ensure that they will seal. Two heavy-duty spherical-roller main bearings support the crankshaft. One heavy-duty spherical-roller bearing supports the connecting rod on the crankshaft. A small leakage of the cryogenic fluid into the dead-gas space maintains the bearing housing at pump liquid inlet pressure. Fluid vaporization pressurizes this zone; passage through the warm-end chevron seals completes the pressurization of the bearing housing. Because the entire system is pressurized at cryogenic fluid pressure, all internal seals and packings experience no pressure differential. As a result, seals and packings must seal only against large-scale fluid transfer. The rotating face seal for the crankshaft, located in the input shaft side bearing cap, seals the bearing housing from atmospheric pressures.

550-4.2.5 WARM-END LUBRICATION SYSTEMS. In the warm-end lubrication system, a splash system lubricates the bearings, wrist pin, and crosshead. The motion of the partially submerged crankshaft connecting rod assembly provides oil spray. Natural convection around the aluminum bearing housing cools the oil.

550-4.2.5.1 A typical cryogenic pump has two openings in the outer casing. The smaller opening serves to vent the vaporized liquid that blows by the piston rings. The larger opening is a valved port that is opened during startup. The open port ensures complete flooding of the pump suction during startup and vents the vapors that form as a result of heat leakage into the suction piping. If the suction piping is short in length and well insulated, and if the pressure of the suction liquid is sufficiently high, this valve may be closed after the pump is operating steadily. Complete operation and maintenance of the pump are covered in NAVSEA 0323-LP-010-6000, **High Pressure Cryogenic Pump, Mod CL-1A-125** .

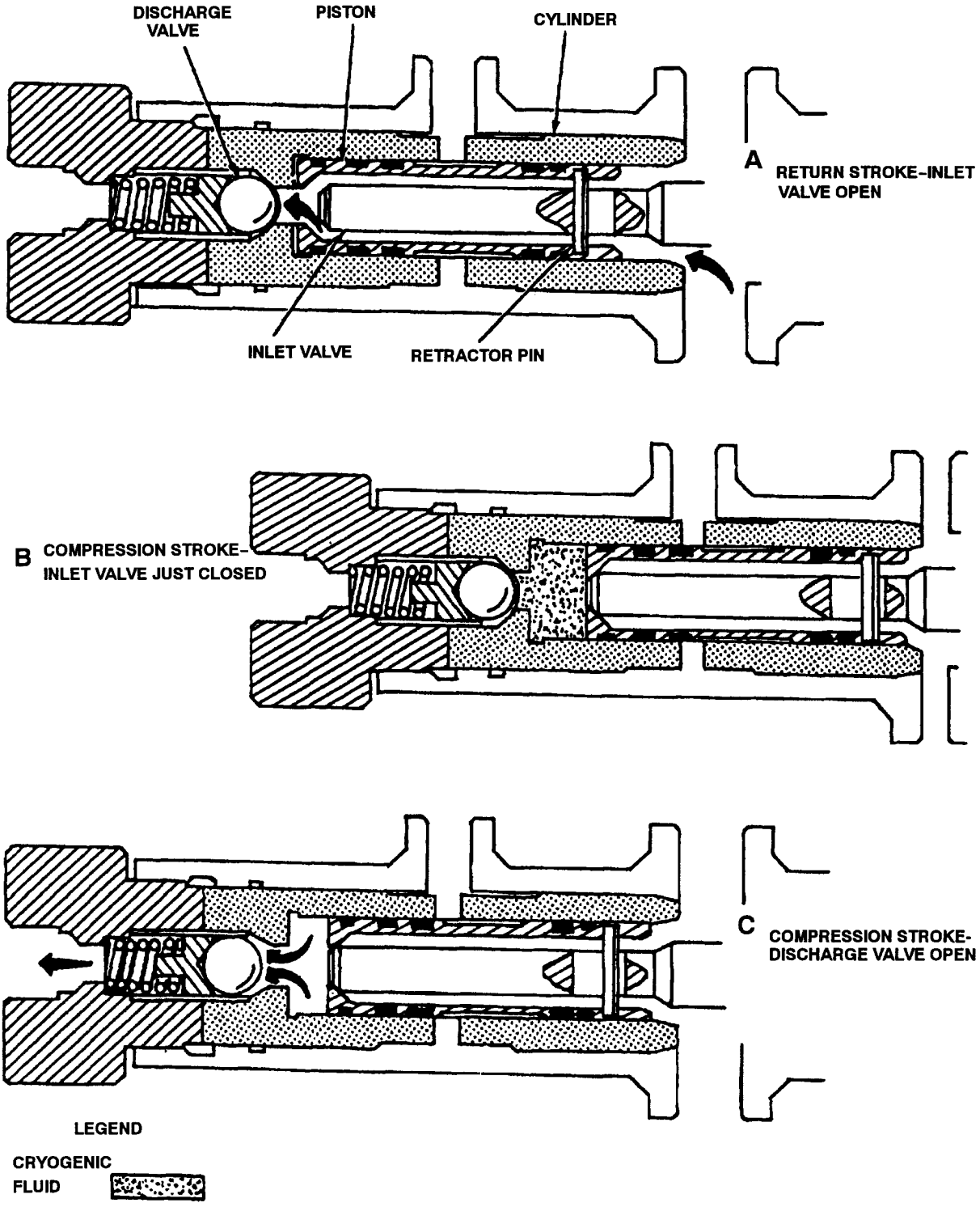

Figure 550-4-2. Cryogenic Pump Inlet Valve and Piston Operation

550-4.2.5.2 A cryogenic liquid can be pumped efficiently only if it is adequately subcooled. That is, it must be at a temperature sufficiently below the boiling point corresponding to the pressure imposed upon it. For this reason, stored liquid oxygen or liquid nitrogen that is to be pumped is often pressurized. The tank's pressure-building coil is opened momentarily, thereby increasing the nonequilibrium gas pressure and subcooling the liquid (see paragraph 550-3.3.3). The degree of required subcooling, expressed as a pressure term, may vary from a few square inches of water to as high as 25 lb/in^2 g, depending upon the pump design. For most shipboard pumps, about 5 to 10 lb/in^2 g is usually adequate.

550-4.2.5.3 Many small shipboard liquid oxygen storage tanks of an early design (prior to 1953) are equipped with integrally mounted, single-piston, high-pressure immersion pumps. The cold ends of these pumps extend down vertically into the tank. This means that the inlet valve is submerged in the liquid, thereby ensuring complete flooding. Despite the absence of intake piping (with associated heat leaks), these immersion pumps still require the liquid oxygen to be subcooled. Applying 5 lb/in^2 g of pressure will produce sufficient subcooling for satisfactory operation.

550-4.3 VAPORIZERS

550-4.3.1 The conversion of pressurized liquid oxygen or liquid nitrogen to the gaseous state may be carried out with various types of heat exchange media. Liquids may also be converted to gases by direct, electrical heat conduction through the walls of the fluid passages. Although steam has been used in some vaporizers, this may lead to temperature control difficulties with the vaporized gas product. Actual freezing of steam condensate may result if the steam supply is inadequate. Similarly, freezing can occur if seawater or ethylene glycol solutions are used. Because of its relatively low heat content, warm air used as a heat exchange fluid may also cause difficulties in temperature control. Because of the difficulties posed by the heat exchange media and because of the greater simplicity inherent in a direct, electrically-heated system, the latter is considered more suitable for shipboard application.

550-4.3.2 The function of the vaporizer is to evaporate the liquid completely and to heat it to a nearly ambient temperature before charging it into storage flasks. Excessively low gas outlet temperatures are undesirable in that they may result in flasks that are brittle or that are over-pressurized after they warm up. Similarly, high gas temperatures may unduly weaken the steel or result in under pressurization. Consequently, both the temperature and the pressure of the vaporization process are usually controlled.

550-4.4 PREVENTIVE MAINTENANCE

550-4.4.1 Conduct cryogenic charging system preventive maintenance in accordance with PMS Maintenance Requirement Cards (MRC's).

SECTION 5.

GAS GENERATING EQUIPMENT

550-5.1 GENERAL

550-5.1.1 This section describes in a general way the shipboard equipment used in the production of oxygen and nitrogen.

550-5.1.2 Oxygen is produced aboard ship either by cryogenic air separation or by electrolysis of water; nitrogen is produced exclusively by cryogenic air separation. Because the air separation process is essentially identical for oxygen and nitrogen, the process for both is covered jointly in this section. The production of oxygen by water electrolysis is then discussed separately.

550-5.2 AIR SEPARATION OPERATIONS

550-5.2.1 GENERAL. Atmospheric air is a gas mixture normally containing approximately 21 percent (by volume) oxygen, 78 percent nitrogen, 1 percent argon, small, variable amounts of water vapor (humidity), about 0.03 percent carbon dioxide, and traces of rare gases. Separating oxygen or nitrogen from this mixture may involve some or all of the following operations:

a. Compression of air, with after cooling.

b. Drying of compressed air by desiccants.

c. Cooling of compressed air with low-pressure return gas.

d. Additional cooling of compressed air by refrigeration.

e. Adsorption of carbon dioxide from the air.

f. Expansion of air, resulting in partial liquefaction.

g. Filtration of air to remove solidified carbon dioxide.

h. Adsorption of hydrocarbons from the liquid.

i. Distillation of the liquefied air, in one or more columns, to separate the oxygen and nitrogen.

j. Removal and storage of the liquid product.

k. Warming-up of the low-pressure gas from the column by heat exchange with high-pressure air.

l. Electrical heating of the low-pressure gas for regeneration of the desiccants and adsorbers.

550-5.2.2 LIQUEFACTION CYCLES. Either of two basic air liquefaction cycles may be employed in the manufacture of oxygen and nitrogen. The first is the high-pressure, or Linde, cycle; the second is the low-pressure, or Claude, cycle.

550-5.2.2.1 High-Pressure Cycle. The high-pressure, or Linde, cycle makes use of the Joule-Thomson gas expansion principle of refrigeration (see Figure 550-5-1). In its simplest form, it requires a high-pressure (up to 3,000 lb/in^2 g) air compressor, heat exchanger, expansion valve, liquid air receiver, and various filters, traps, and other components (not shown). Purified compressed air, traveling in the direction of the arrows, expands through the expansion valve. This same air returns by way of the heat exchanger, thereby progressively cooling the system until liquid air temperatures are reached in the receiver. Modifications of this cycle, including the use of an auxiliary refrigerator, are found in shipboard air separation plants.

550-5.2.2.2 Low-Pressure Cycle. The low-pressure, or Claude, cycle is based on the thermodynamic principle that compressed air loses heat when used to drive a reciprocating engine or turbine (see Figure 550-5-2). It consists of a low-pressure (100 to 500 lb/in^2 g) air compressor, heat exchangers, expansion engine, expansion valve, liquid air receiver, and accessory controls (not shown). In the Claude cycle, the compressed air, after partial cooling by back-flowing low-pressure air, is split into two streams. One stream passes through a second exchanger and the expansion valve into the liquid air cooler. The uncondensed cold air from the collector returns through

the two heat exchangers. The second stream passes through the expansion engine. The cold engine exhaust returns by way of the two exchangers. Usually, the major portion (80 to 85 percent) of the intake air passes through the engine; the remainder passes through the expansion valve. Auxiliary refrigeration is not normally required in the Claude cycle as it is in a modified Linde cycle. A unit quantity of compressed air is cooled much more in expanding through an engine than in passing through an expansion valve without performing work. However, high refrigeration efficiency in the Claude cycle is strongly dependent upon careful engineering and construction. Modifications of this cycle, operating with 85-100 lb/in^2 g inlet air, are used in shipboard air separator plants.

550-5.3 OXYGEN-NITROGEN PLANTS

550-5.3.1 GENERAL. High-pressure and low-pressure air liquefaction cycles are used to produce both oxygen and nitrogen of high purity. Both high- and low-pressure plants currently are installed on aircraft carriers and submarine tenders. All such plants require at least two distillation columns to separate air effectively into its two major components. A simplified schematic flow chart for a typical shipboard liquid oxygen-gaseous nitrogen plant is given in Figure 550-5-3.

550-5.3.2 HIGH-PRESSURE OXYGEN NITROGEN PLANTS. Normal high-pressure oxygen-nitrogen plant production processes and possible variations are covered in paragraphs 550-5.3.2.1 through 550-5.3.2.5.3.

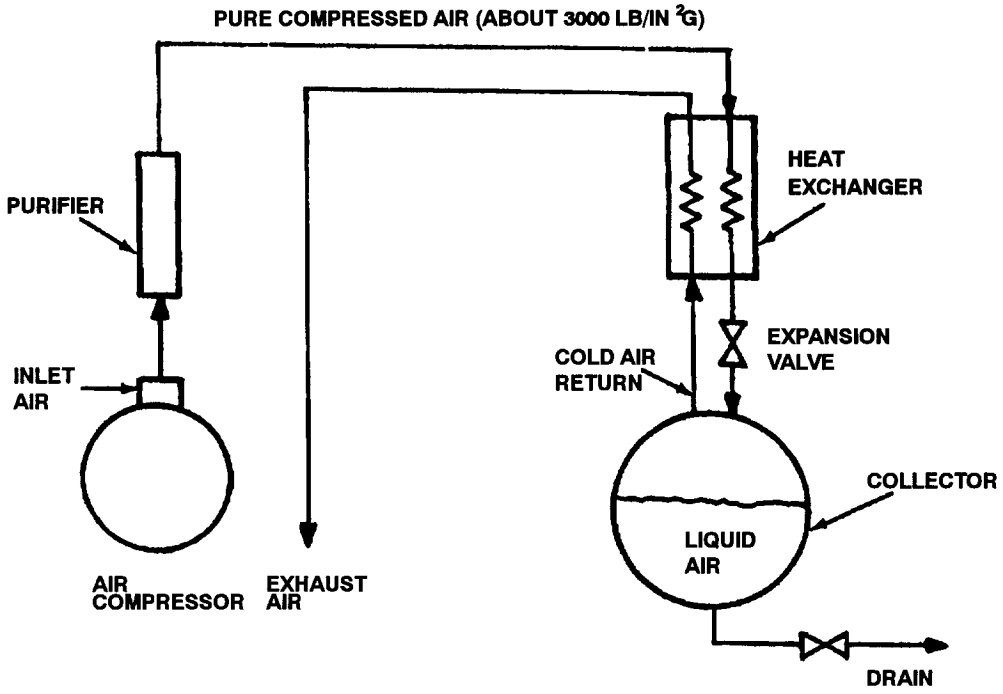

Figure 550-5-1. High-Pressure Cycle

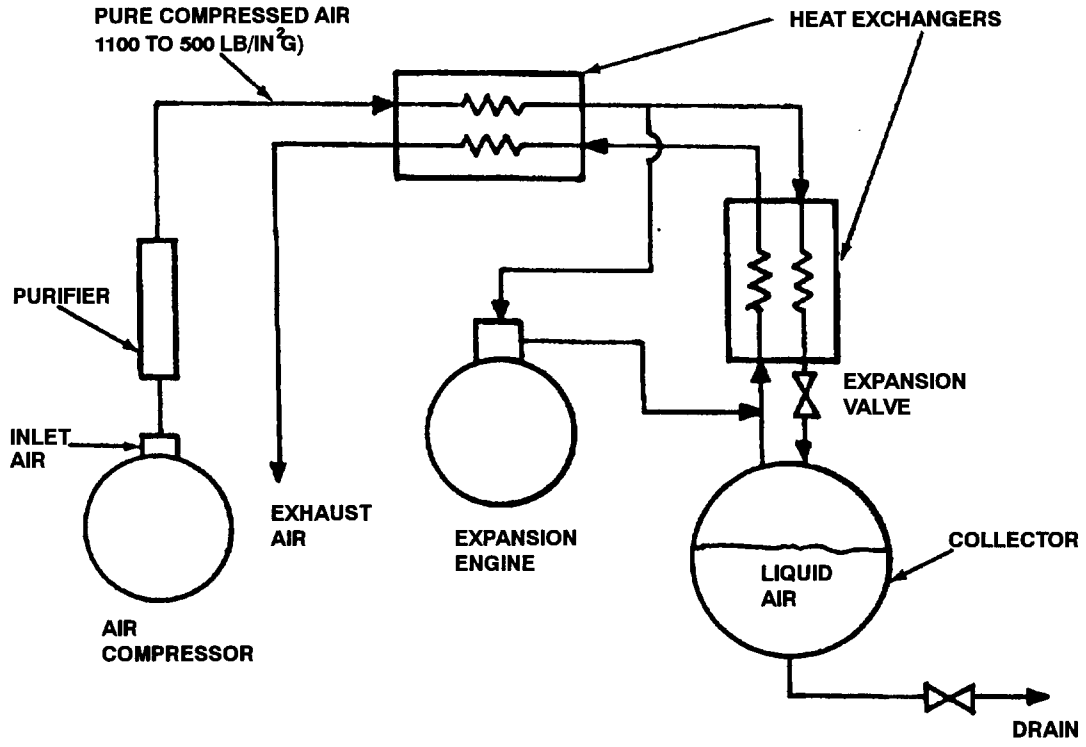

Figure 550-5-2. Low-Pressure Cycle

550-5.3.2.1 Operation. In normal high pressure oxygen-nitrogen plant operation, the compressed air passes in succession through the oil filler-separator, an air dryer, and a carbon dioxide adsorber filter to remove water vapor, carbon dioxide, and particulate matter. The air is then cooled by back-flowing waste gas in one or more heat exchangers and in the refrigerated exchanger. The refrigerant used in the latter is refrigerant 22 (R-22), which has been condensed by the auxiliary refrigerant unit. Functioning as the refrigerant evaporator, the condensed R-22 circulates in a closed loop through the refrigerated exchanger. Finally, on passage through the expansion valve, the cold, high-pressure air partially liquefies. The partially liquefied air enters the first or high-pressure distillation column at about 100 lb/in^2 g pressure. The liquefied air collects in the column sump, while the gaseous portion travels up the column, passing from one tray to the other and contacting down-flowing liquid on each tray.

550-5.3.2.1.1 Liquid air from the high-pressure column sump expands into a second, or low-pressure, column at some intermediate point. It also supplies reflux liquid. Part of the liquid leaving the condenser tubes (essentially pure nitrogen) is directed to the product storage tank. Liquid nitrogen leaving the top of the high-pressure column transfers to the top of the low-pressure column through an expansion valve. The transferred liquid supplies reflux liquid to this low-pressure column. Some liquid nitrogen from the condenser returns to the top of the high-pressure column. This liquid nitrogen falls down the column from tray to tray and, in doing so, strips oxygen from the rising gas. The boiling liquid oxygen generates vapors that travel up the low pressure column. The vapors strip nitrogen from the descending reflux liquid and become richer in nitrogen as they reach the top. The reflux is distilled to about 99.5 percent pure oxygen. It condenses the nitrogen gas entering the condenser tubes from the high-pressure column below. The boiling liquid oxygen is withdrawn directly to storage. The usual practice is to maintain pressure of 100 lb /in^2 g or less in the high-pressure column and 15 lb/in^2 g or less in the low-pressure column. By virtue of these pressure differences, the liquid oxygen (which normally boils at a higher temperature) is cold enough to condense the rising nitrogen vapors in the high pressure column.

550-5.3.2.1.2 To ensure adequate purity of the products, it is necessary to remove excess uncondensed gas from the system. This gas is referred to as waste gas and is used not only to cool the incoming compressed air, but also to reactivate the dryers and carbon dioxide adsorbers. Molecular sieve, silica gel, or activated alumina are used as adsorbents in the air dryers and carbon dioxide adsorbers to remove water vapor and carbon dioxide from the air.

550-5.3.2.1.3 Waste gas generated by the air distillation process cools the main heat exchanger. Upon leaving the exchanger, this gas is heated electrically to about 288°C (550°F) and passes through the dryer and adsorber, which is to be reactivated. After adsorbed water and carbon dioxide have been removed, the electrical heater shuts down and the unheated waste gas cools the dryer and adsorber. At designated time intervals, the inlet compressed air stream is switched from one dryer and adsorber to the other. The saturated dryer and adsorber is reactivated and cooled in preparation for further service. For simplicity, the various valves necessary to effect alternation of dryers and adsorbers are not shown in Figure 550-5-3. It is possible to draw off only oxygen or only nitrogen; or liquid nitrogen and liquid oxygen may be simultaneously drawn off in any proportion. The resulting products will be at least 99.5 percent pure; and the combined liquid production rate will be essentially constant.

550-5.3.2.2 Variations. Several variations of high-pressure oxygen-nitrogen generating cycles are used in shipboard plants (see Figure 550-5-4). These are described in considerable detail in technical manuals applicable to the equipment installed in each ship (see Table 550-5-1). Several variations are also discussed in paragraphs 550-5.3.2.3 through 550-5.3.2.5.3.

550-5.3.2.3 High- and Low-Pressure Columns. Height limitations may make impossible the installation of one column above the other as is the practice in shore installations. In such cases, the low-pressure column is placed alongside the high pressure column. When the columns are located one above the other, they are physically connected with a heat exchanger, a condenser-reboiler. In this heat exchanger, heat energy is removed from the gaseous nitrogen at the top of the high-pressure column, and the nitrogen condenses in what is referred to as the exchanger's tube side. Liquid oxygen in the bottom of the low pressure column fills what is referred to as the exchanger's shell side. The liquid oxygen removes the nitrogen's heat energy, heat energy from the nitrogen boils the liquid oxygen, and the oxygen vapors flow up through the distillation column.

550-5.3.2.3.1 If the low-pressure column is placed alongside the high-pressure column, there is no integral condenser-reboiler between them. The nitrogen condenser is located at the top of the high-pressure column, and heat exchange fluid must be brought from another part of the process. In such plants, the condenser is kept filled with liquid oxygen by means of a small mechanical pump or a vapor lift pump that takes suction from the bottom of the low-pressure column. This is again the standard double-column, condenser- reboiler process in which the condensing nitrogen's heat energy boils the liquid oxygen. The oxygen vapors are piped from the nitrogen condenser to near the bottom of the low-pressure column and flow up through the distillation column. The liquid oxygen comes from the low-pressure column and its boil-off vapor returns through a closed loop to almost the same place. As a result there is insufficient pressure differential to force the liquid oxygen up to the low-pressure column top. The pump provides the flow force.

550-5.3.2.3.2 In other plants, the pressure-driven flow from a high pressure point to a lower-pressure point keeps the nitrogen condenser filled with heat exchange fluid. No pump is needed. In some of these plants the fluid is oxygen-rich liquid air (crude oxygen) from the high-pressure column bottom. This air goes to the nitrogen condenser and then, by means of other processing, to the low-pressure column. In other plants, the fluid is nitrogen-rich air from the high-pressure column. After other processing, this fluid goes to the nitrogen condenser, which is at a low pressure.

NOTE

Other processing refers to heat exchange, expansion, division into and combination with other process streams that serve the air separation process. Other processing includes the removal of heat energy to condense the high-pressure column nitrogen and the addition of heat energy to boil and distill low-pressure column oxygen.

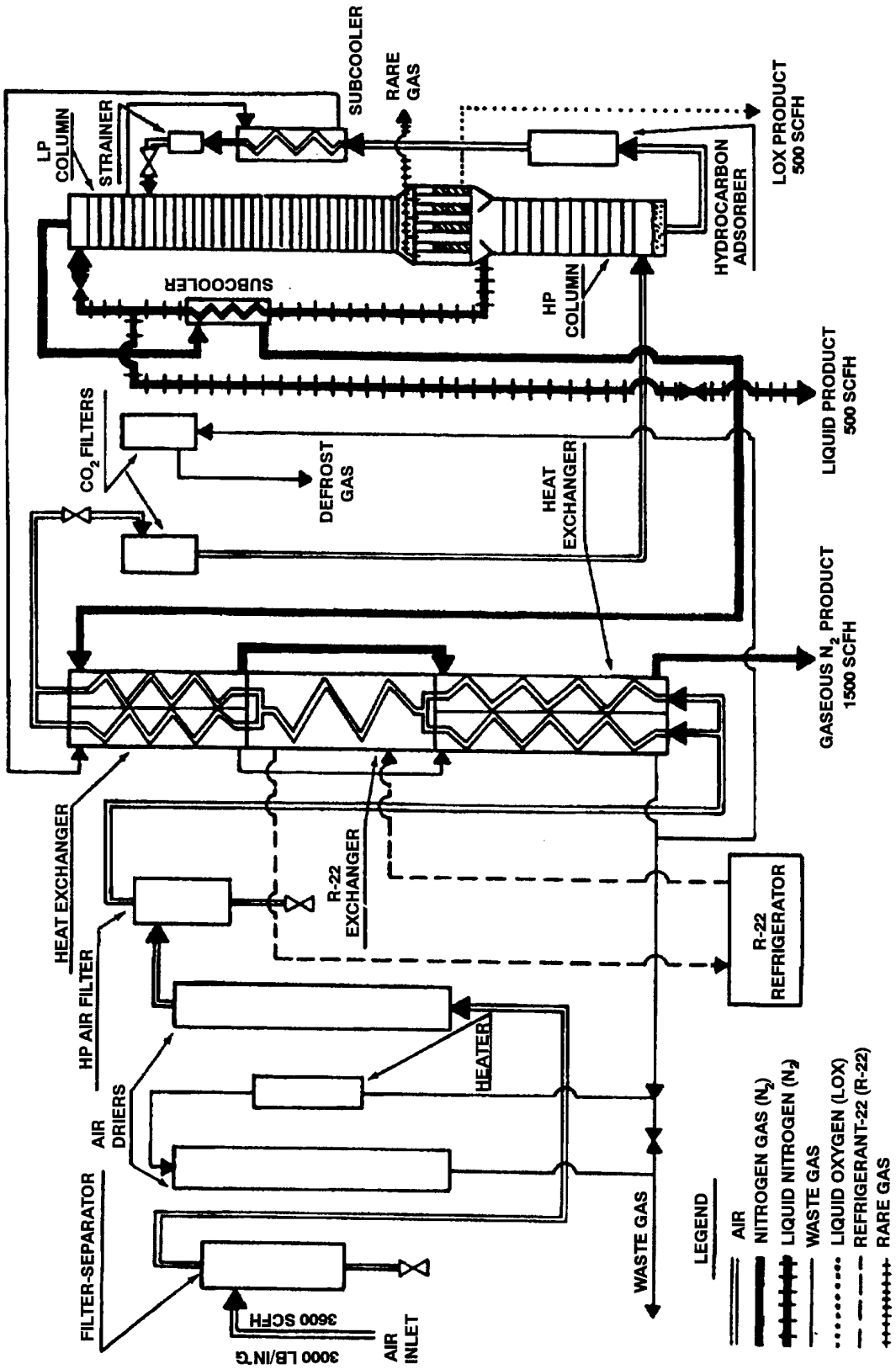

Figure 550-5-3. Liquid Oxygen-Nitrogen Plant, Flow Diagram

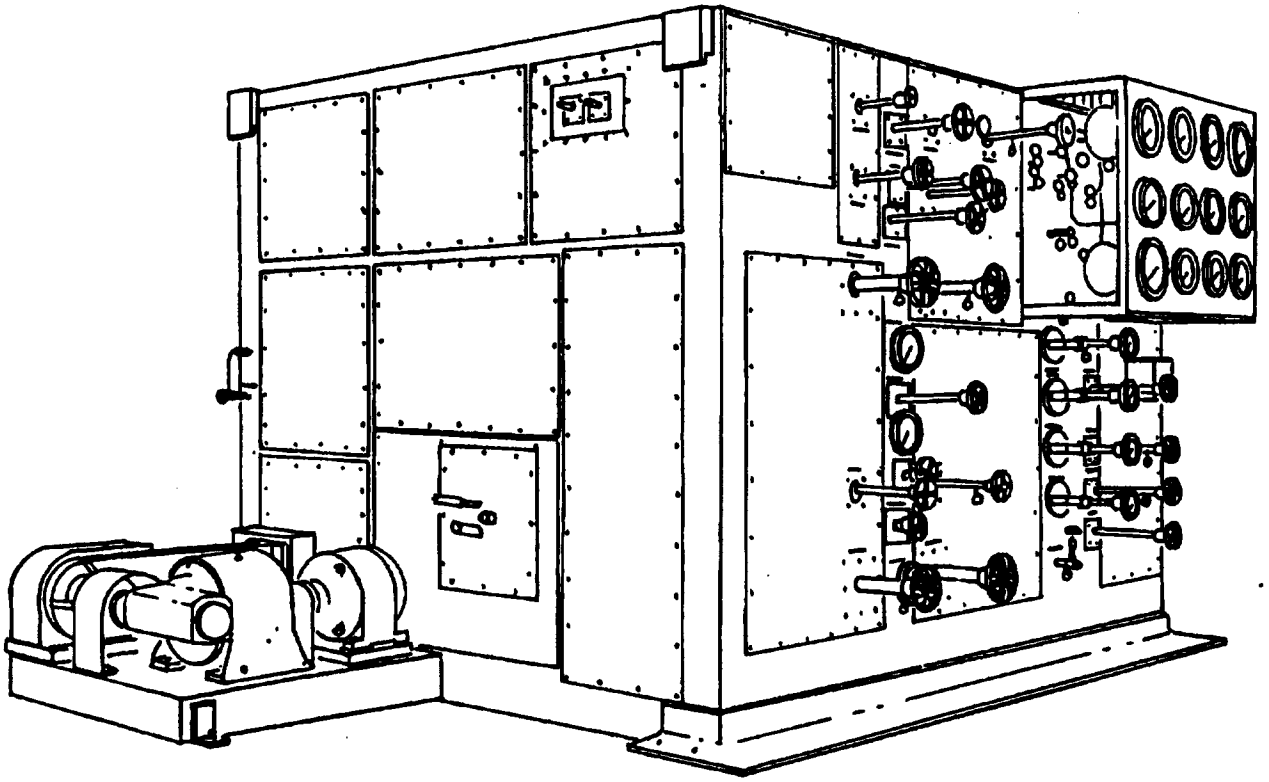

Figure 550-5-4. Large-Capacity Oxygen-Nitrogen Plant

Table 550-5-1. REFERENCES FOR HIGH-PRESSURE OXYGEN-NITROGEN PLANTS

NAVSEA Identification Number	Title
0323-LP-004-7000	Shipboard Oxygen and Nitrogen Generating Plant, Model LGSB 80-30
0323-LP-005-5000	Shipboard Oxygen-Nitrogen Generating Plant, Model LGSB 80-30A
0323-LP-009-4000	Liquid Oxygen and Nitrogen Plant, Model J6287
0323-LP-010-3000	Shipboard Oxygen-Nitrogen Generating Plant, Model LGSB 80-30B
0923-LP-003-7010	Liquid Oxygen-Nitrogen Plant, Model J64107
0923-LP-004-1010	Liquid Oxygen-Nitrogen Plant, Model J68114
0923-LP-001-6010	Shipboard Oxygen-Nitrogen Generating Plant

550-5.3.2.4 Pumping of Liquid Oxygen. Liquid oxygen is pumped from the bottom of the low-pressure column to the nitrogen condenser at the top of the high-pressure column. The vapor-lift pump is considered more reliable and trouble-free than a conventional pump because of the absence of moving parts. This pump moves the liquid oxygen to a higher elevation by heating it with nitrogen gas in submerged coils. The heating process causes bubble formation and reduces the bulk density of the liquid. Vapor-lift pumps also conserve refrigeration. No heat enters the system as a result of electrical energy input, as would be the case with a conventional mechanical pump. Nevertheless, because designing a well-functioning vapor-lift pump process is as much art as science, the use of a mechanical pump is authorized between adsorption and reactivation periods.

550-5.3.2.5 Removal of Contaminants. Adsorbent beds containing a molecular sieve, activated alumina, or silica gel remove moisture, carbon dioxide, and hydrocarbons from process air in oxygen-nitrogen plants. Mois-

ture and carbon dioxide are removed by means of two parallel adsorbent beds located in the air piping upstream of the high-pressure column. The two beds are alternated between adsorption and reactivation periods (refer to paragraphs 550-5.3.2.1.2 and 550-5.3.2.1.3).

550-5.3.2.5.1 All shipboard oxygen-nitrogen plants have moisture removal beds to dry the air received from the air compressors before any cooling is done. Some also remove the carbon dioxide at that same stage of the process. Others have carbon-dioxide removal silica gel beds located at a later point in the process. In these plants, the carbon dioxide is not removed until after heat exchange and Joules-Thomson expansion have chilled the air to near liquefaction.

550-5.3.2.5.2 At the low-process temperature, silica gel has a high affinity for carbon dioxide and selectively absorbs it from the air. Hydrocarbon adsorption, primarily for acetylene removal, is done in a crude oxygen process stream. Most plants have a single hydrocarbon adsorber that is reactivated upon production run completion. There are also plants with two parallel adsorbers that alternate between adsorption and reactivation.

550-5.3.2.5.3 Adsorbers are reactivated with nitrogen-rich (usually 89-94 percent) gas that is a byproduct of the oxygen-nitrogen producer process. The byproduct gas serves various purposes and the process could not operate without it. It is referred to as waste gas because, once it has served its purpose, it is vented or wasted to atmosphere. For adsorber reactivation, some of the low-pressure waste gas (essentially water- and carbon dioxide-free) is heated. The heated gas is then passed through an adsorber to desorb (remove) the contaminants (reactivation) and is vented to atmosphere. Further along in the process, either in liquid oxygen, liquid-air, or crude-oxygen piping, there is a hydrocarbon adsorber (either a single bed or a parallel pair).

550-5.3.3 LOW-PRESSURE OXYGEN-NITROGEN PLANTS. Normal low-pressure oxygen-nitrogen plant production processes and possible variation are covered in paragraphs 550-5.3.3.1 through 550-5.3.3.2.

550-5.3.3.1 Operation. In normal operation, air compressed at a pressure of 85 to 100 lb/in^2 g passes in succession through a water separator, a regenerative- or reversing-type heat exchanger, and adsorber(s). The heat exchanger cools the air to approximately -168°C (-270°F) and removes water and carbon dioxide by freeze-out on the heat exchanger's cold surfaces. The adsorber(s) remove the last traces of carbon dioxide and remove hydrocarbons from the air. Then the air is split into two separate streams.

550-5.3.3.1.1 One stream of air is combined with a warmer side stream of air from the heat exchanger and has a resultant temperature of approximately -151°C (-240°F). The side stream is necessary to maintain the refrigeration balance and cold-end temperature differential of the heat exchanger. The combined stream expands through and turns a turbo expander. In doing this work, the air is forced to release heat energy, reducing its temperature to approximately -182°C (-295°F). The air then refrigerates the liquefier (which is a heat exchanger) and the regenerative- or reversing-type heat exchanger.

550-5.3.3.1.2 The second of the split air streams is refrigerated in the liquefier to the point of partial air liquefaction. The partially liquefied air is introduced to the distillation column, either directly or by way of a liquid-vapor phase separator.

550-5.3.3.1.3 A variation of the process has a third air stream split out after the regenerative- or reversing-type heat exchanger. This third stream goes directly to the distillation process section; the second air stream goes by way of the liquefier and the first goes to the expansion engine as previously described.

550-5.3.3.1.4 The distillation process for the low-pressure plant functions in the same way as for the high-pressure plant. For a more extensive discussion of the production process and component design, see NAVAIR 06-30-501, **Oxygen/Nitrogen Cryogenic Systems** .

550-5.3.3.2 Modifications. For information on low-pressure oxygen-nitrogen generating cycle modifications found in shipboard plants, refer to NAVSEA manuals listed in Table 550-5-2.

Table 550-5-2. REFERENCES FOR LOW-PRESSURE OXYGEN-NITROGEN PLANTS

NAVSEA Identification Number	Title
0923-LP-004-8010	Oxygen and Nitrogen Plant Liquid, Model GB-2
0923-LP-010-9010	Liquid Oxygen-Nitrogen, Shipboard, Type J-72078
0923-LP-011-2020	Liquid Oxygen-Nitrogen Plant Producer, Model GB-2A, Volume II
S9553-AC-MMI-010	Liquid Oxygen-Nitrogen Plant, Model GB-2AS
S9553-AG-MMO-010	Liquid Oxygen-Nitrogen Plant, Model GB-3

550-5.4 OXYGEN-NITROGEN PLANT PREVENTIVE MAINTENANCE

550-5.4.1 GENERAL. Over a period of time, it is possible for an oxygen-nitrogen plant to become contaminated with oil. This results from oil entering the air from oil-lubricated air compressor(s) or from a leaky turbo expander. The plant can also become contaminated with gases, vapors, and fumes drawn into the air compressor intake. These contaminants are not compatible with oxygen. When exposed to oxygen, they can cause a fire or explosion or can make the oxygen unusable.

550-5.4.1.1 Preventive maintenance measures must be taken to ensure safe operating conditions and prevent oil contamination. If a Planned Maintenance System (PMS) is installed, shipboard, preventive maintenance shall be conducted in accordance with Maintenance Requirement Cards (MRC's).

550-5.4.2 HIGH-PRESSURE PLANTS. Closely observe the following points during the operation of high-pressure plants:

1. Ensure that oil-lubricated compressors are not excessively lubricated.
2. Prevent compressor discharge line filters from becoming oil-saturated.
3. Reactivate and renew desiccant in the dryers and adsorbers periodically as specified in the applicable instruction manual.
4. Solvent-wash and purge the producers periodically.

550-5.4.2.1 Safety standards for maintenance of all high-pressure shipboard plants must include washing the high-pressure air circuit once every 1 to 1-1/2 years under normal operation and the oxygen side of the condenser circuit once every 3 years. Any time any of these circuits or any other component is suspected of being exceptionally dirty or contaminated, it shall be washed. The high-pressure air circuit consists of the desiccant air dryers, heat exchangers, carbon dioxide adsorbers, and associated components and piping. It does not include the high-pressure distillation columns.

550-5.4.3 LOW-PRESSURE PLANTS. Closely comply with the following during operation of low-pressure plants.

1. Check for oily drainage from water separator and for other indications that compressor oil is entering the air (refer to air compressor instruction manual troubleshooting guide regarding seal or bearing problems).
2. Check for indications that turbo expander oil is entering the air: abnormal oil pressure or consumption, abnormal seal air pressure, oil mist in waste gas discharge, or abnormal turbo expander noise indicating possible seal or bearing damage.
3. Reactivate and renew adsorbents periodically as specified in the applicable instruction manual.
4. Clean (flush) and purge the plants periodically. A safe interval for cleaning (flushing) low-pressure, shipboard plant process circuits is once every 2 to 3 years under normal operation.

550-5.5 OXYGEN-NITROGEN PLANT CLEANING

550-5.5.1 If samples drawn from liquid oxygen and oxygen-nitrogen plants are found (by copper acetylide tests, odor tests, or infrared analysis) to contain excessive hydrocarbons or other contaminants, clean system in accordance with MIL-STD-1330 and re-certify in accordance with MIL-STD-1630.

NOTE

Oxygen and nitrogen systems shall be cleaned and certified only by personnel qualified in accordance with MIL-STD-1630.

550-5.6 ELECTROLYTIC OXYGEN GENERATOR

550-5.6.1 GENERAL. In an oxygen-nitrogen plant, oxygen is generated by the electrolytic oxygen generator. There are two designs in use: model 6L16 used primarily on SSN class submarines, and model 7L16, used on SSBN class submarines. (See Figure 550-5-5.)

550-5.6.2 OPERATION. The electrolytic oxygen generator is designed to produce breathing oxygen for enclosed environments in submarines. It does this by the electrolysis of demineralized or deionized water in 16 high-pressure cells (cylinders) connected in series. During this process, deionized water mixed with potassium hydroxide is used as a conductive compound in the high pressure cells. A small, direct high-current voltage is applied across two electrodes within each cell. The current flowing from one electrode to the other through the potassium hydroxide solution causes the distilled water to break down into its basic component gases, oxygen and hydrogen. For a simplified view of the remainder of the generating process, see Figure 550-5-6 and paragraphs 550-5.6.2.1 through 550-5.6.5.1.

550-5.6.2.1 Electrolytic oxygen generator cells are designed so that gases are collected separately and flow into their respective process headers. The oxygen gas bubbles flow up through the potassium hydroxide solution at the positive electrode (ANODE). The bubbles rise to an oxygen header. Here they are directed to high-pressure storage banks or bled into the confined submarine atmosphere, replacing the oxygen used up by the ship’s crew.

550-5.6.2.2 Similarly, the hydrogen gas leaves the potassium hydroxide solution at the negative electrode (CATHODE). It is then directed to the hydrogen header for disposal overboard.

550-5.6.2.3 Each cell contains high- and low-liquid-level sensors. These sensors automatically supply the cells with deionized water to replace water lost during the electrolytic production of oxygen and hydrogen gases.

550-5.6.2.4 Prior to their discharge from the electrolytic oxygen generator, the gases pass through moisture traps and a gas-purity analyzer system. They are ultimately discharged from the generator to the ship's storage or disposal facilities. The oxygen gas produced has a purity of 99.5 percent.

550-5.6.2.5 Electronic or pneumatic detectors in the electrolytic oxygen generator continually monitor all conditions that could affect the desired performance. The detectors sense any abnormal performance or unsafe condition and automatically either adjust for a given problem or shut down the generator.

550-5.6.2.6 Although similar in basic processes, electrolytic oxygen generator models 6L16 and 7L16 differ in design functions. Model 6LI6 is a totally electronic unit in regard to gas process control, monitoring, and safety circuits. This means that oxygen and hydrogen control valves, the gas-purity sampling system, and the electrical safety circuits are all electronically controlled. Model 7L16, on the other hand, combines electrical circuitry and an electro-pneumatic control system to control the gas-handling process.

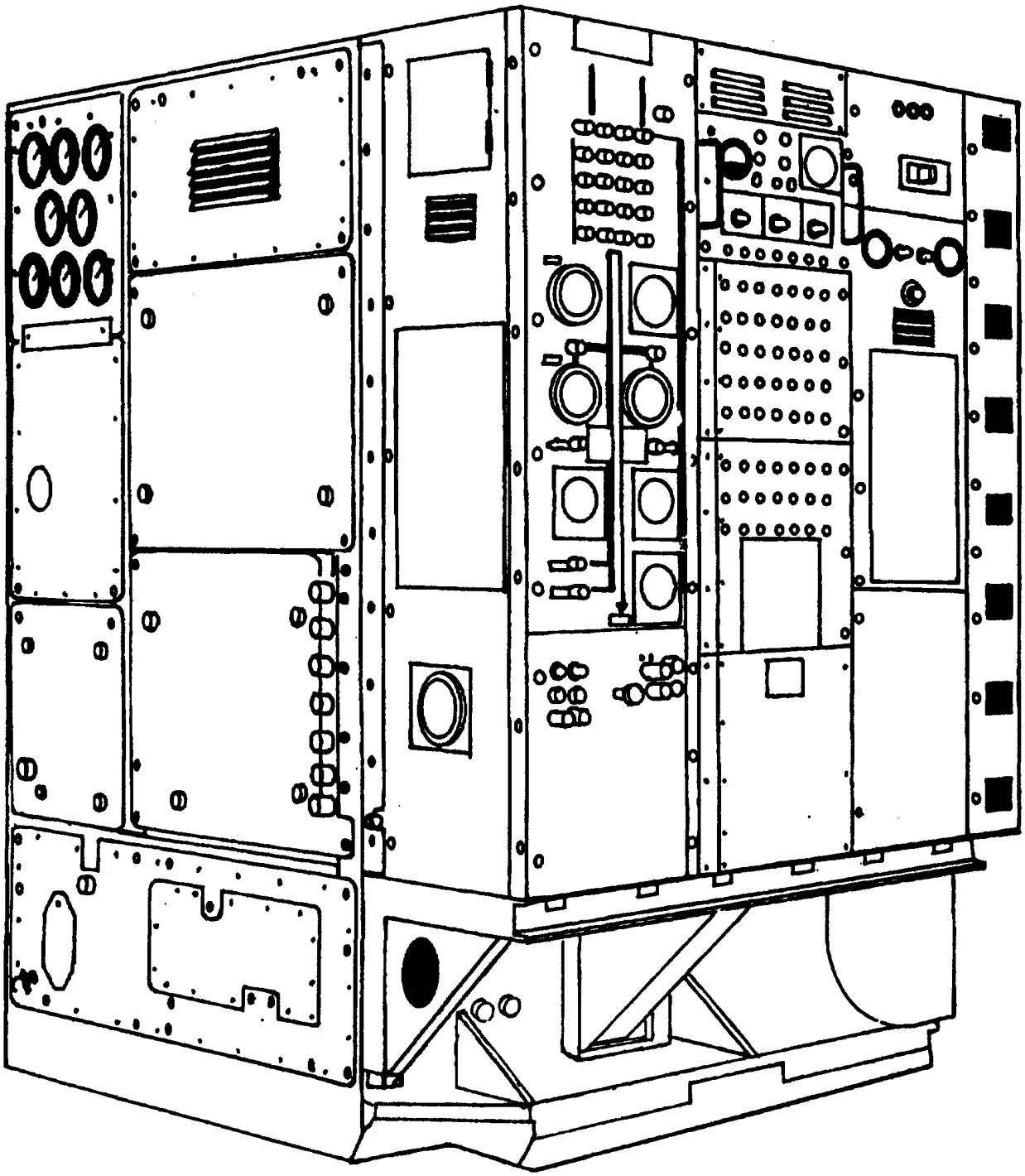

Figure 550-5-5. Electrolytic Oxygen Generator Model 7L16

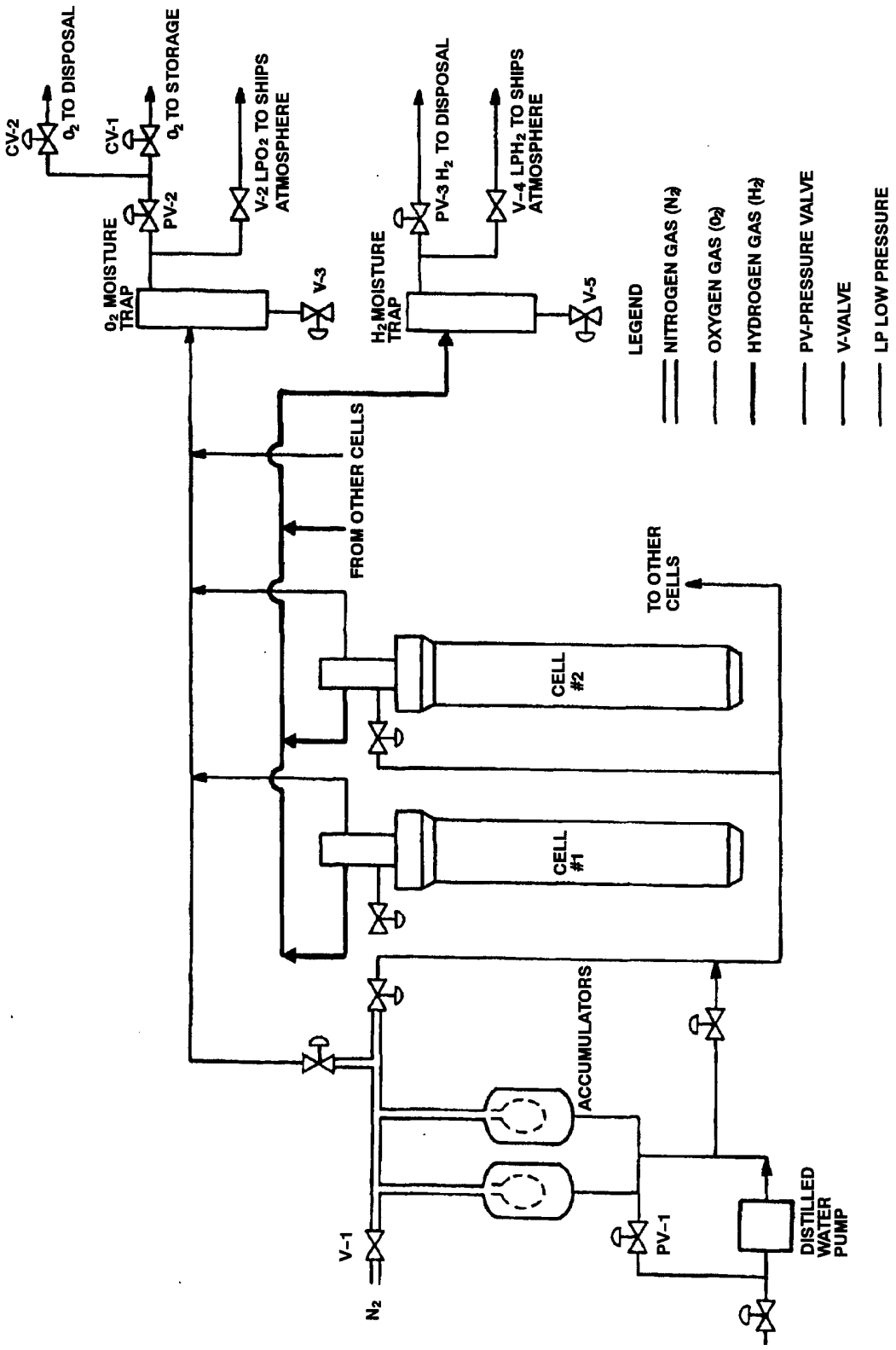

Figure 550-5-6. Electrolytic Oxygen Generator, Simplified Flow Diagram

550-5.6.3 STRUCTURE. Both electrolytic oxygen generator models 6L16 and 7L16 have a cell area and several cubicles, as follows:

a. **Cell Area** - The cell area contains 16 electrolytic cells, process piping, and headers for the oxygen, hydrogen, and cooling water systems.

b. **Auxiliary Cubicle(s)** - The auxiliary cubicle(s) contain(s) manual valves, process piping, control valves, pressure switches, transducers, a distilled water pump, and pressure gages.

c. **Rectifier Cubicle** - The rectifier cubicle contains components to convert 400 volts a.c. input to about 50 volts d.c. power for the electrolytic cells, ancillary control, and monitoring circuits.

d. Either:
   1. **Control Cubicle (6L16)** - The control cubicle contains electronic control and monitoring circuitry.
   2. **Pneumatic Control Cubicle (7LI6)** - The pneumatic control cubicle contains the gas analyzer chassis, electro-pneumatic solenoids, air pressure reducers, motor controllers, and pneumatic pressure controls.

550-5.6.4 SYSTEMS. The electrolytic oxygen generators consist of several systems:

a. **Nitrogen System** - The nitrogen system performs the following functions:
   1. Allows pressurization before startup, thereby providing a means of leak detection. Being an inert gas in this application, nitrogen is ideally suited for this type of test.
   2. Retains nitrogen in two internally-mounted (model 7L16), or two or four externally-mounted (model 6L16) accumulators. Accumulated nitrogen is used in purging the generator cells of oxygen and hydrogen gases for maximum safety after generator shutdown.

b. Damp pulsation of the distilled water pump.

c. **Distilled Water System** - The distilled water system replenishes the distilled water consumed in the electrolytic process. It also maintains a positive pressure on the nitrogen in the accumulators during generator purging.

d. **Oxygen System** - The oxygen system incorporates piping, valving, indicators, and controllers to discharge oxygen gas from the generator to the ship's oxygen storage facilities or to disposal.

e. **Hydrogen System** - The hydrogen system provides a means for removing hydrogen from the cells. It is similar to the oxygen system, but directs the removed hydrogen to the ship's disposal system.

f. **Cooling System** - The cooling system maintains normal operating temperatures of 87.8°C-93.3°C (190°F-200°F) (model 6L16) or 40.5°C-54.4°C (105°F-130°F) (model 7L16) in the cell area through use of heat exchanger arrangements. Chilled water or seawater-cooled air (model 7L16) or auxiliary freshwater (model L616) is used as a cooling medium, depending on ship configuration.

g. **Electrical System** - The electrical system consists of a d.c. power supply, electronic controls, relays, meters, solenoid valves, electric contactors, and switches. The electrical system provides monitoring, control, and continuous scanning of safety circuits during oxygen generation. It will shut down the electrolytic oxygen generator if a fault occurs. The electrical system also serves as a control system (model 6L16) that automatically:
   1. Controls the water level in the 16 cells;
   2. Provides visual indication of normal or abnormal conditions of system control functioning; and,
   3. Shuts down the electrolytic oxygen generator in any abnormal condition. The fault-indication circuits for the electrical system (models 6L16 and 7L16) continuously self-check. Any electrical failure in these cir-

cuits shuts down the oxygen generator. Additionally, a gas analyzer system samples oxygen and hydrogen that is passed through separate analyzers. The findings (the percentage of each gas in samples of the other) are indicated on gas analyzer meters. If sample readings exceed the predetermined percentage settings, safety circuits will activate to shut down the electrolytic generator. Hydrogen in the atmosphere in the auxiliary cubicle(s) and cell area is analyzed and indicated on the hydrogen leak meter. The electrical control system also controls the sequential purging of individual electrolytic cells.

h. **Pneumatic System** - The pneumatic system (model 7L16) primarily functions to supply air to operate and control the electrolytic valves and sensors. These valves and sensors are used in the electrolytic oxygen generator to manufacture gas and to operate pneumatic control valves and control the process variables. In addition, air operates the pneumatic water level valves (LCV's model 7L16) to control the water level in the 16 cells.

550-5.6.5 ANCILLARY EQUIPMENT. The electrolytic oxygen generator, model 7L16 , cooling system maintains normal operating temperatures in the cell area. To do this, it uses a heat exchanger, fan, and a cooling medium of seawater or chilled water. The cooling medium used depends upon individual ship configuration. Model 6L16 is cooled by the use of the auxiliary freshwater system. Additionally, the cooling system includes a cell area temperature-sensing device that will shut down the electrolytic generator to protect the cells from high temperatures. Normal operating temperatures are from 87.8°C-93.3°C (190°F-200°F) for model 6L16 and 40.6°C-54.4°C (105°F-130°F) for model 7L16.

550-5.6.5.1 Detailed descriptions of the construction, operation, and repair of the oxygen generator, model 6L16, are given in NAVSEA 0923-LP-000-8010, -8020, and -8030, **Electrolytic Oxygen Generator, Model 6L16** , volumes I, II, and III, respectively. Detailed descriptions of the construction, operation, and repair of model 7L16 are given in NAVSEA S9515-AC-MMM-010 and -020, **Electronic Oxygen Generator, Model 7L16** , volumes I and II.

550-5.7 CHLORATE CANDLE OXYGEN GENERATION

550-5.7.1 GENERAL. The chlorate candle is a mixture of sodium chlorate, iron, small quantities of barium peroxide, and a fibrous binding material. The mixture is pressed into a cylindrical shape about 6-1/2 inches in diameter and 12 inches long. The cylinder is packaged in a metal can with a tear strip at one end. When ignited, the candle burns without flame, releasing oxygen and leaving a residue of iron oxide and sodium chloride. Each candle burns 40 to 60 minutes and releases about 115 cubic feet of oxygen, the equivalent of approximately 115 man- hours. A candle adds approximately 0.6 tons to the air conditioning load in the space in which it is burned. Candles become very hot and must be handled with heat-protective gloves (NSN 8415-01-092-3910) in accordance with MIL-G-44013. An aerosol of sodium chloride is produced during combustion and must be filtered out of the oxygen.

550-5.7.1.1 Chlorate candles require a temperature over 204°C (400°F) for ignition and will not ignite spontaneously on contact with oil. However, it is desirable to keep oil from contact with the metal can or the candle itself. Although chlorate candles are a very safe form for stowing oxygen, they should be treated with the same meticulous care as any other oxygen source.

550-5.7.2 CANDLE STOWAGE. Stow chlorate candles in a clean, dry location that is easily identifiable and that is free from oil spray or drippage (see paragraph 550-5.8). Remove candles from shipping containers before stowing. Secure candles adequately to ensure against damage to the airtight containers during ship rolling and pitching. Never stow candles with ammunition or pyrotechnics. Separate stowage is desirable, but candles may

be stowed with clean, dry stores. Keep the stowage area clean and free from dunnage and packing materials. Do not allow the ambient temperature of the stowage area to exceed 100°C (212°F). Keep away from open flames such as welding torches and halide torches. Stow the candles in such a way that all portions of the storage space are accessible.

550-5.7.3 CANDLE CONTAMINATION. Dirt, oil, or grease on the candle container may inadvertently come in contact with the candle material when the container is opened. This could result in a fire and the production of carbon dioxide when the candle is burned. Before opening a dirty container, thoroughly clean it with warm water and detergent. If a candle container has been accidentally punctured or has corroded or deteriorated in stowage or handling, assume that the candle is contaminated and jettison it. Do not open candles until just prior to use.

550-5.7.4 FURNACE DESCRIPTION AND CHARGING. Candles are burned in a furnace comprised of a steel frame supporting the combustion chamber, a cylinder approximately 7 inches in diameter and 25 inches high, and a particulate filter (see Figure 550-5-7). A cover at the top of the combustion chamber permits access to the chamber. The cover is fitted with a pressure gage and a pressure relief device in case of sudden and excessive rise in pressure from any cause. The oxygen produced is vented through the chamber cover, piped to a particulate filter, and discharged to the ship's atmosphere. The furnace should be mounted in a manner that prevents accidental tilting but permits easy tilting of the combustion chamber for insertion and removal of candles.

550-5.7.4.1 Charge the furnace as follows:

1. Remove the lids of two candle containers, using the tear strips.
2. While both the combustion chamber and containers are tilted to an angle of 45 degrees or more, slide the two candles from their containers into the combustion chamber. Do not drop the candles into a vertical chamber; dropping may crack them, stopping combustion at the crack. In performing this operation, avoid touching the candle itself, in order to eliminate the risk of contaminating it with dirt or grease.
3. Insert a new ignition nail through the combustion chamber lid.
4. Return the combustion chamber to the vertical position and close.

550-5.7.5 CANDLE IGNITION AND BURNING. To ignite the top candle: push the ignition nail down so the phosphorous-coated head bears against the candle; twist to produce a rubbing action. This rubbing action ignites the ignition cone that is pressed into one end of each candle during manufacture. The ignition cone contains the same materials as the candle but in a different ratio to facilitate ignition. Each candle will burn 40 to 60 minutes, releasing oxygen at a fairly steady rate. The flow of oxygen through the filter will build up a slight pressure in the combustion chamber. This pressure change will be observed on the pressure gage. When the two candles are consumed (in 90 to 100 minutes), the gage will return to zero.

550-5.7.6 CANDLE DOUSING. Once a candle is lit, allow it to burn completely. If it becomes absolutely necessary to douse the candle, take advantage of its breakable nature. Tip the combustion chamber on its side and hit it vigorously on the deck. When the candle stops burning, the pressure in the chamber will drop to zero. Allow the combustion chamber to remain on its side until cool before attempting to remove the remainder of the candle. Discard the unburned portion; do not reignite it (see paragraph 550-5.7.7). Candles can also be doused by cooling water.

550-5.7.7 CANDLE DISPOSAL. Using asbestos gloves and the insulated handle on the combustion chamber, transfer the remains of each candle, the clinker, to a galvanized iron bucket. To transfer, either tip the combustion chamber down or remove it completely and invert it. When first removed, the clinker is red hot inside. Set the disposal bucket and clinker aside to cool in a location where there is no personnel hazard or fire risk. Cooling can be hastened by putting about a pint of water in the bucket before the clinker is dumped. However, this will increase the humidity load in the space. Handle the furnace and the clinker carefully and cautiously, using heat protective gloves (see paragraph 550-5.7.1). Dispose of or jettison the clinker after it has cooled.

550-5.7.8 SMOKE FILTER. A fiberglass smoke filter is provided on each furnace to remove the sodium chloride smoke generated by burning a candle. Normally a filter will perform satisfactorily for three or four furnace charges. An increase in pressure as shown on the furnace pressure gage will indicate the saturation of the filter. When the indicated pressure reaches 5 lb/in^2 g, remove the smoke filter and replace it with a clean one before burning more charges. Clean the saturated smoke filter by flushing with clean water until all salt has been washed out. Then dry and seal the filter for future use. If a leak develops in the filter, discard the filter. If a filter is used too long without cleaning, it may cause a pressure buildup that will activate the pressure relief valve. Smoke and hot oxygen will escape as a result.

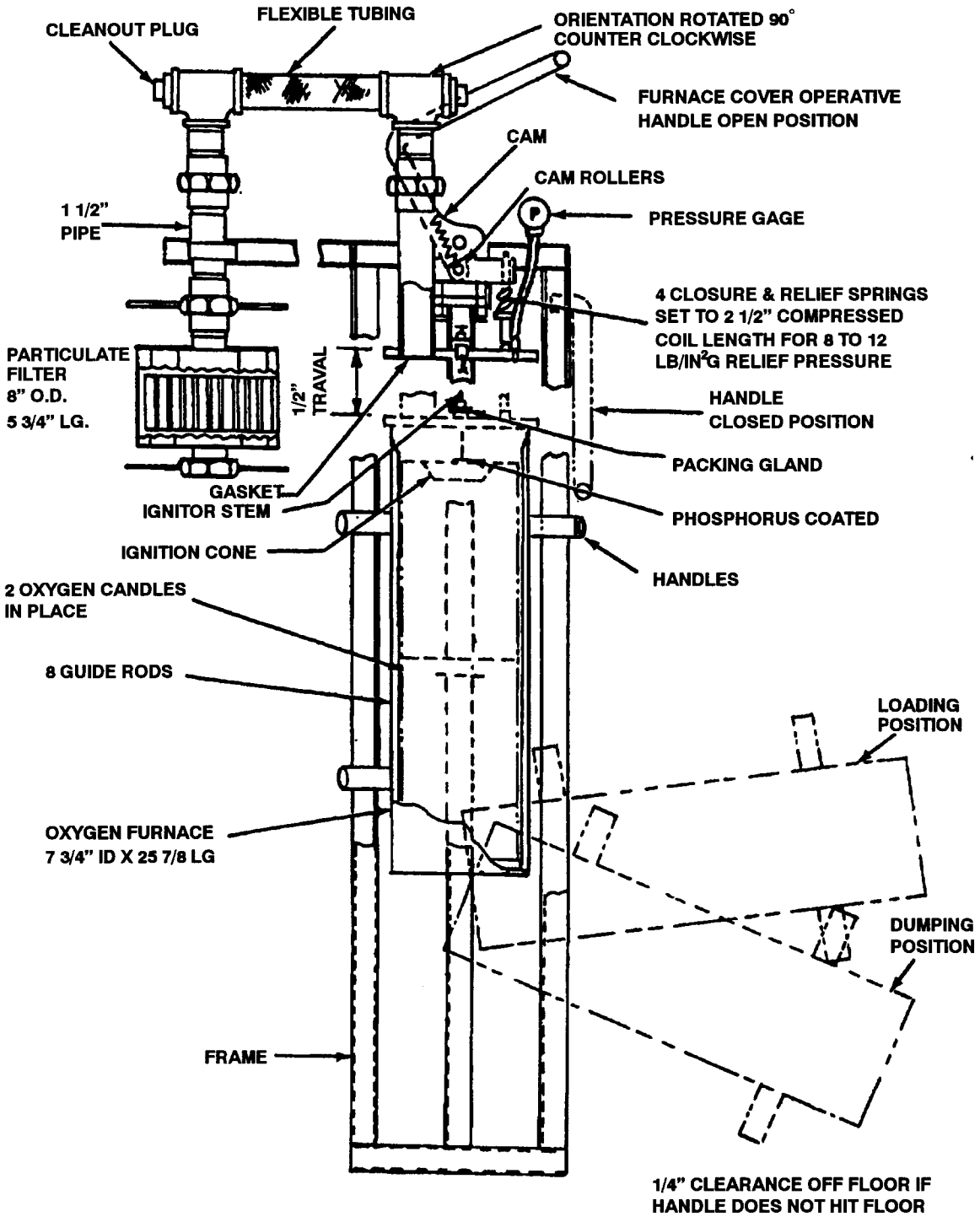

Figure 550-5-7. Oxygen Candle Furnace Assembly

550-5.7.9 SAFETY PRECAUTIONS. Observe the following safety precautions to ensure safe oxygen candle stowage, burning and handling and to ensure uniform oxygen concentration throughout the submarine:

a. Burn oxygen candles in an area with good local air circulation so that high concentrations of oxygen will not develop. Maintain good circulation between the compartment and the rest of the submarine.

b. Protect candles carefully. Candles burn in a downward plane. The candle material just below this plane is in a semimolten state. Vibration or heavy shock may separate the solid and semimolten parts of the candle and cause the candle to go out.

c. Allow a lit candle to burn completely. (For procedure if candle absolutely must be put out, see paragraph 550-5.7.6).

d. Pipe the oxygen produced by candle combustion to a discharge terminal of an air-conditioning recirculation system.

e. Position the furnace out of the way of traffic. This will reduce the danger of burns by accidental contact with the hot candle container.

f. Keep the furnace area free from oil drips, dunnage, clothing, and other combustibles.

g. Stow unused candles out of the immediate vicinity of the burning candle.

h. Identify the candle stowage area by posting a conspicuous sign. Ready identification will facilitate the special action required in the event of a fire within the compartment.

i. If there is a fire outside the compartment, periodically douse the candles with water to maintain them at below-ignition temperature. If fire threatens the stowage area itself, consider removing the candles.

j. Inspect the stowage compartment for cleanliness and freedom from hazard before candles are loaded. Reinspect stowage area periodically while candles are onboard. Also check the compartment when candles are offloaded or consumed to make sure that none are overlooked.

550-5.8 INERT GAS PRODUCERS

550-5.8.1 Ships (such as LPHs, LPDs) that store large quantities of gasoline require significant volumes of inert gas. On these ships, inert gas is used for blanketing cofferdams and purging fuel lines for fire protection purposes. For these applications, inert gas can be defined as a nonflammable gas that does not support combustion. It may consist of:

a. One hundred percent carbon dioxide.

b. A mixture of nitrogen, argon, and oxygen containing no more than 3 percent oxygen by volume.

c. A mixture of carbon dioxide, nitrogen, and a maximum of 3 percent oxygen.

If both inert gas and oxygen are needed by the ship, the mixture in b. above is provided by means of an oxygen-nitrogen plant as described in paragraph 550-5.3.1. However, if inert gas alone is required, it may be more economical to generate the mixture in c. above. A simple combustion and purification process that will do this is described in subsequent paragraphs.

550-5.8.2 Inert gas (as defined in paragraph 550-5.8.1) is generated by the controlled combustion of gasoline or jet fuel in air. If the burner is properly adjusted, the process requires only a slight excess of air to convert all the fuel to carbon dioxide and water vapor. The nitrogen in the air is essentially unreacted so that undesirable toxic

and corrosive by-products, such as carbon monoxide and oxides of nitrogen, are minimal. Present procurement specifications limit by-product gases to the following maximums.

a. Carbon monoxide - 0.1 percent by volume

b. Hydrogen - 0.1 percent by volume

c. Oxides of nitrogen - 10 parts per million by weight

550-5.8.3 A schematic flow diagram of an inert-gas plant is shown in Figure 550-5-8. This plant is intended to be operated in conjunction with an 800 lb/in^2 g gas compressor to permit pressurized storage in the product gas. The basic plant (as shown) consists of a fuel storage tank, fuel filter and pump, air filter and blower, burner, combustion chamber, gas cooler, freshwater cooling system, and moisture separator. In addition, the plant has a variety of temperature, pressure, and name controls that are not illustrated. In some units, the combustion gases are quenched directly in flowing seawater to effect simultaneous cooling and purification; in others, burner design minimizes the formation of oxides of nitrogen and other contaminants. Still another modification consists of alining a catalyst bed with the combustion chamber in order to reduce the nitrogen-oxide concentration. Details regarding operation and maintenance of the several varieties of inert gas plants are given in the NAVSEA technical manual listed in Table 550-5-3.

550-5.9 PREVENTIVE MAINTENANCE

550-5.9.1 If PMS is installed, shipboard preventive maintenance of all gas generating equipment shall be conducted in accordance with MRC's.

Table 550-5-3. INERT GAS PLANT REFERENCES

NAVSEA Identification Number	Title
0323-LP-005-8000	Producer, Gas, Inert, Shipboard Model 40
0923-LP-008-2000	Gas Producer, Inert
0323-LP-009-7000	Producer, Gas, Inert, Shipboard Model 6205
0393-LP-017-5000	Fire Extinguishing System in Gas Producer Series, PA-43

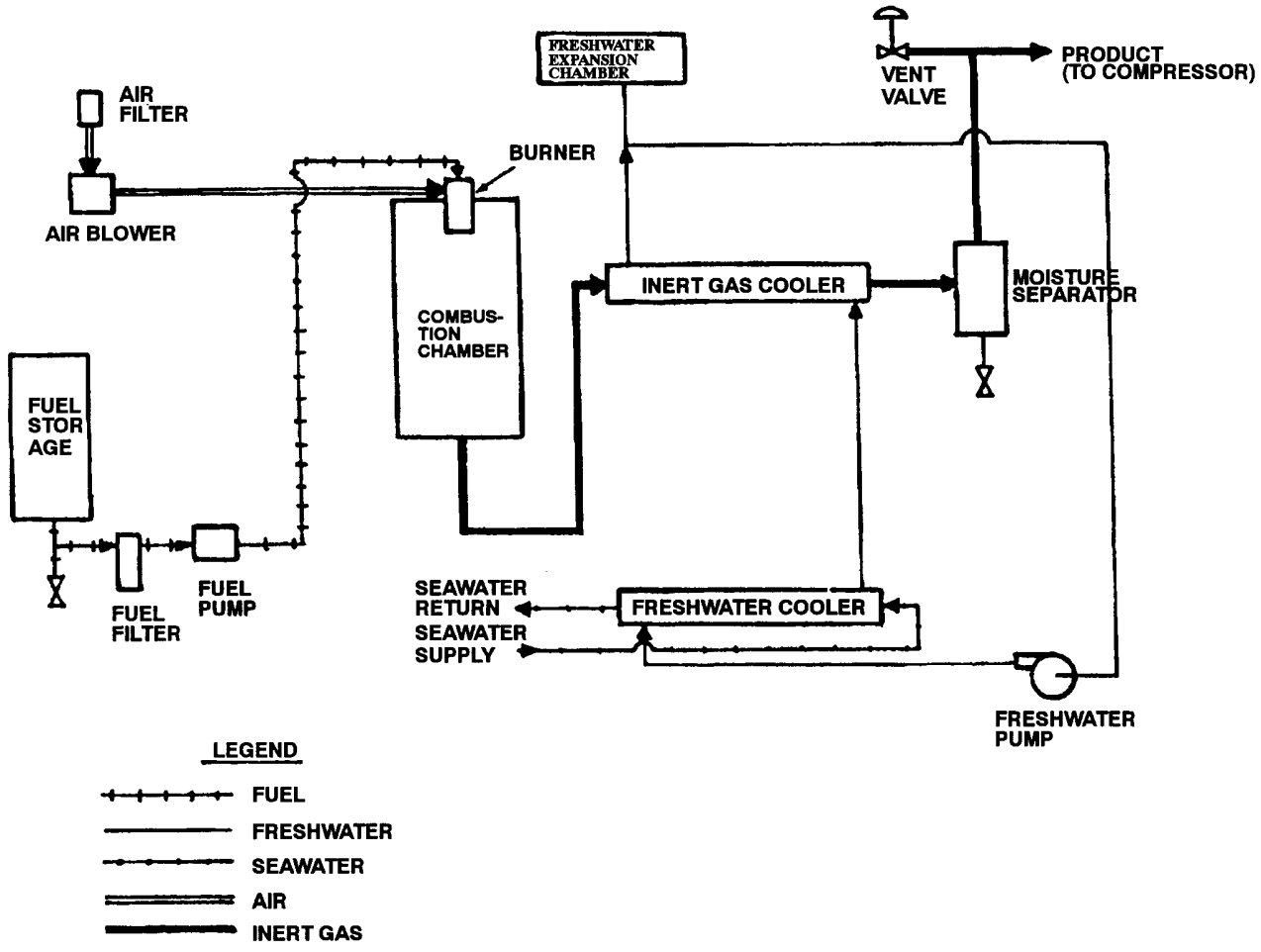

Figure 550-5-8. Inert Gas Plant: Schematic Flow Diagram

SECTION 6.

LIQUID AND GASEOUS OXYGEN OR NITROGEN PERSONNEL PROTECTION AND SAFETY PRECAUTIONS

550-6.1 SCOPE

550-6.1.1 This section is a compilation of safety precautions for personnel involved in the operation of liquid and gaseous oxygen systems and equipment. These precautions have been drawn from several sources such as equipment technical manuals, NAVSEA instructions, and recommendations from commercial suppliers of liquid and gaseous oxygen. To a lesser extent, precautions regarding nitrogen handling are also included. Consult applicable technical manuals for maintenance and repair procedures for specific shipboard equipment. Procedures peculiar to particular equipment have not been included.

550-6.2 PHYSICAL AND CHEMICAL PROPERTIES OF OXYGEN

550-6.2.1 LIQUID OXYGEN. Liquid oxygen is a pale blue, transparent fluid with a boiling point of -183°C (-297°F) and a specific gravity of 1.14 at atmospheric pressure. One gallon of liquid oxygen weighs 9.53 pounds,

as compared to one gallon of water, which weighs 8.34 pounds. Upon vaporization, a gallon of liquid oxygen will occupy approximately 115 cubic feet at 21.1°C (70°F) and at atmospheric pressure. At the temperature of liquid oxygen, many metals and other materials become brittle. Under ordinary conditions, liquid oxygen boils vigorously and produces a voluminous vapor cloud.

550-6.2.2 GASEOUS OXYGEN. Gaseous oxygen is colorless and odorless and has a specific gravity of 1.105 compared to air. It is not flammable but strongly supports and rapidly accelerates the combustion of all flammable materials. Gaseous oxygen will cause combustible materials (notably oil and grease) to burn spontaneously and may cause some substances to burn that are not normally considered combustible (e.g., steel wool, thin gage metals, and certain types of cloth). Any substance that burns in a normal atmosphere will burn more rapidly and with a higher flame in concentrated oxygen. Oxygen by itself can neither burn nor explode; a fuel is required.

NOTE

Always call oxygen by its proper name. Oxygen should never be called air and should never be used in place of compressed air.

550-6.3 PERSONNEL TRAINING

550-6.3.1 SURFACE-SHIP AIR SEPARATION OXYGEN-NITROGEN PLANTS. Only qualified personnel with full knowledge and understanding of the applicable safety requirements and hazards associated with oxygen production and handling shall be permitted to handle gaseous and liquid oxygen aboard ship. Equipment such as producing plants, storage tanks, and pump-vaporizer units shall be operated only under the supervision of a Fleet Training Center (FTC) Cryogenics School graduate.

550-6.3.1.1 Ideally, all operating personnel, as well as supervisory personnel, will be graduates of the Cryogenics School. There may be cases, however, in which sufficient personnel with this training are not available. In this event, operators trained by the petty officers in charge may be used if the following requirement is met: personnel who are not Cryogenics School graduates shall participate in oxygen production or handling only after demonstrating a thorough comprehension of the processes and equipment involved.

550-6.3.2 SHORE OXYGEN RECHARGER UNITS. Only qualified operators (graduates of the FTC Cryogenics School) shall operate or service oxygen recharging units and associated charging equipment ashore. Other personnel who are required for charging operations shall be thoroughly trained and qualified by the senior Navy school graduate prior to being placed on watch.

550-6.3.3 SUBMARINE OXYGEN GENERATING EQUIPMENT. Submarine oxygen generating equipment shall be under the supervision of personnel trained at the U.S. Naval Submarine School, New London. Refresher maintenance courses on this equipment are given at the Fleet Ballistic Missile (FBM) Submarine Training Center, Charleston, and at the Fleet Submarine Training Facility, Pearl Harbor.

550-6.3.4 TRAINING FILMS. The following training films are available for personnel indoctrination in handling liquid and gaseous oxygen: **MN 8364B - Liquid Oxygen, Safe Handling and Storage MN 9959 - Gaseous Oxygen and Nitrogen Charging of Submarines** .

550-6.4 PROTECTIVE CLOTHING AND SAFETY SHOWERS

550-6.4.1 Special protective clothing and safety showers are required in order to safeguard personnel from the hazards of exposure to liquid oxygen and nitrogen. Liquid oxygen and nitrogen, because of their low temperatures, can produce serious frostbite if they contact the skin.

a. While loading or unloading portable liquid oxygen or nitrogen containers, wear the following:
   Face shield (NSN 9G4240-00-202-9473)
   Safety shoes (NSN 9D8430-00-926-9965)
   Leather gloves (loose fitting) (NSN 9D8415-00-268-7860)

b. Handle cold piping, valves, and other parts only with leather gloves (NSN 9D8415-00-268-7860). When charging liquid oxygen or nitrogen Dewar flasks or converters, wear a rubber apron (NSN 9D8415- 00-082-6108).

c. Wear clean clothing (coveralls, white NSN 9D8415-00-279-8719). Take care to avoid spilling cryogenic liquid on the clothing.

d. Before beginning a liquid oxygen or nitrogen handling operation, note the availability and proximity of shower, sink faucet, eye/face bath, or pail as a water source. A deluge type safety shower is provided in oxygen-nitrogen plant spaces for personnel protection. In many installations the showers are supplied from the fire main to ensure availability of water supply under all conditions. Some showers are supplied with freshwater. The deluge showers are actuated by pull-chain control valves.

550-6.5 TREATMENT PROCEDURES FOR LIQUID OXYGEN AND NITROGEN INJURIES

550-6.5.1 Serious injury may result if liquid oxygen or nitrogen comes into contact with the skin and is not removed at once. If liquid oxygen or nitrogen has caused the skin to blister or has come in contact with the eyes, the injury must be considered serious. Immediate attention by a physician is required. If liquid oxygen has spilled on clothing, remove clothes as rapidly as possible without causing static ignition. Remove clothing on which liquid nitrogen has been spilled as rapidly as possible also. However, do not allow clothing removal to delay quick immersion or bathing of affected parts with large quantities of water at room temperature. It is of primary importance that liquid oxygen or nitrogen be washed from the skin, or diluted, as rapidly as possible to prevent extensive damage to the tissues. Because of their extremely low boiling point, liquid oxygen and nitrogen in contact with the skin draw heat from the body at a very rapid rate. The result is frostbite or freezing of the affected parts. The evidence of such injury appears on the outer skin as a burn, but the tissues below may actually be frozen. Do not rub or massage the injured parts. Rubbing or massaging may tear or bruise the frozen tissues, possibly resulting in gangrene.

550-6.5.2 General first aid for these injuries is as follows:

a. Do not rub or massage the affected parts under any condition.

b. As rapidly as possible, immerse or bathe the affected parts with water at room temperature (lukewarm).

c. Rapidly remove clothing over the affected area, but do not try to remove clothing that sticks to the skin. Cut around the part that is stuck and leave it for a physician to remove.

d. Keep the victim lying down if practicable.

e. If the skin has blistered (similar to second degree burns) or if the eyes have been in contact with liquid oxygen or nitrogen (even though there is no immediate pain):
   1. **DO NOT BREAK THE BLISTERS.**
   2. Apply wet compresses (warm water).
   3. Transport the victim to a physician as soon as possible.

f. If the injury is less serious (similar to first degree burns as evidenced by a reddening of the skin):
   1. Apply burn pads or dry dressing.
   2. **DO NOT APPLY PETROLATUM JELLY** (or other treatment) to the affected area.
   3. Consult a physician as soon as possible.

550-6.6 SURFACE SHIP OXYGEN-NITROGEN PLANT SAFETY PRECAUTIONS

550-6.6.1 GENERAL PRECAUTIONS. The following precautions shall be observed by all personnel concerned with air separation oxygen-nitrogen plants:

a. Do not smoke or permit smoking or the presence of any matches or cigarette lighters in the compartments where the oxygen-nitrogen plant and liquid oxygen storage tanks are located. Post **NO SMOKING** signs in compartments where liquid oxygen is handled and where gaseous oxygen cylinders are charged or handled. Also, post **NO SMOKING** signs wherever gas piping (including overboard vent piping) is installed.

b. Do not store flammable materials in or adjacent to the plant compartments.

c. Secure all oxygen-handling operations while the ship is loading or offloading fuel.

d. Keep all compartments where oxygen is being handled clean and neat. Inspect gaseous oxygen and nitrogen piping at least once every 3 months.

e. Make certain that a plentiful supply of clean (dust-free) air passes through the compartment at all times when filling operations are under way; when liquid oxygen is stored in the compartment; or when the nitrogen system within the compartment is pressurized.

f. Avoid venting oxygen into any ship compartment. Minor venting is considered acceptable provided that there is adequate ventilation to sweep out the quantity of gas vented.

g. Do not drain or vent oxygen into a closed compartment or anywhere else where adequate ventilation has not been established.

h. Do not remain in an oxygen-rich atmosphere. Personnel breathing an excess of oxygen may experience dizziness, numbness, or mental confusion. These conditions will correct themselves without after-effects once the normal balance of carbon dioxide in the blood is restored. Adequate ventilation will prevent this minor hazard.

i. If excessive concentrations of gaseous oxygen are suspected of being present in any ship compartment, secure all operations that must be secured for safety reasons. Immediately leave the compartment.

j. In handling equipment that contains liquid oxygen, be extremely careful to avoid letting the cold liquid contact the body or clothing. Avoid touching any cold surfaces. Cold surfaces will be covered with frost.

k. When making repairs to oxygen equipment, use parts and tools that have been degreased by ship's personnel with approved cleaning solvent (NSN G685000-983-0282) in accordance with MIL-C-81302. The only acceptable alternative parts are those packaged and marked, **Cleaned for Oxygen Service** .

l. Do not paint or allow painting to be done in the vicinity of the plant compartment while the plant is in operation or converters are being filled.

m. Do not use oil or any petroleum-based lubricant in any equipment where the oxygen can come into contact with the lubricant. Use only the approved lubricants listed in **NSTM Chapter 262, Lubricating Oils, Greases, and Hydraulic Fluids and Lubrication Systems** .

n. Do not attempt to make repairs to oxygen or nitrogen equipment if the equipment contains gas under pressure or contains liquefied gas. Purge oxygen equipment with clean, dry nitrogen before performing any repairs.

o. Do not use any of the following materials around oxygen equipment under conditions that might allow pure oxygen to come into contact with them:

Acetylene
Alcohol
Butane
Cloth
Cork
Dirt
Dust
Grease
Hydrogen
Oil
Paint
Paper
Soap
Tar
Wood

p. On some ship installations, a bucket is used to carry off liquid oxygen during oxygen plant defrost operations. This bucket must be degreased prior to use. Do not allow liquid oxygen to come in contact with steel decks. If it does, flush immediately with water. Steel plating cracks when in contact with liquid oxygen.

q. Request permission from the ship's Commanding Officer to dump liquid oxygen. The ship's overboard discharge must be clear of piers or other ships before this operation is undertaken.

550-6.6.2 OXYGEN TRANSFER OPERATION PRECAUTIONS. During transfer of liquid oxygen and the charging of gaseous oxygen, observe the following precautions.

a. Keep sparks and open flames away from all oxygen-producing, storage, pumping, and vaporizing equipment. Prohibit smoking, painting, welding, cutting, fueling, battery charging, and ammunition handling within 50 feet of liquid oxygen transfer or gaseous oxygen charging operations.

b. Use only nonspark-producing tools for all connecting and disconnecting evolutions, i.e., when replenishing or offloading submarine oxygen systems.

c. When transferring liquid oxygen, do not leave valve all the way open. Open valves wide, then immediately close them about one quarter turn; otherwise, they may become stuck in the open position and seem to be tightly closed.

d. Do not confine liquid oxygen between two closed valves in a piping system or in a container, flask, or cylinder that is not provided with a vent or relief device. Extremely high pressure will build up unless vented. When all liquid in a container has evaporated, secure the vent valve to prevent contaminants from entering.

e. To compensate for temperature changes, make adequate provision for expansion and contraction of all liquid oxygen-carrying piping.

550-6.6.3 MATERIAL PRECAUTIONS. Combustible material shall never be used in liquid oxygen systems. Approved construction materials are low-carbon stainless steel, aluminum alloy, copper, silicon bronze, nickel, nickel-copper and copper nickel. Materials unsuitable for construction of liquid oxygen systems include carbon steel, cast iron, plastics, and rubber.

550-6.6.3.1 Use only equipment made or treated specifically for oxygen service. Use valve packing, O-rings, and gasket material of a type approved by NAVSEA for oxygen service. Use water-mixed valve regrinding compound that is free from oil or grease. Repair oxygen equipment and oxygen piping by using spare parts and tools that have been cleaned per MIL-STD-1330. Observe the following precautions when making repairs.

a. Do not use petroleum- or alcohol-based solvents at any time.

b. Do not use oil for servicing oxygen gages. Oxygen gages should be marked, **For Oxygen Service. Use No Oil.**

c. Do not attempt repair until pressures are released.

d. Purge oxygen equipment and piping with dry, oil-free air or nitrogen before repairs are made. Ensure that equipment is at ambient temperature.

e. Use only approved lubricants and thread compounds. Use materials sparingly. For list of approved lubricants, see **NSTM Chapter 262, Lubricating Oils, Greases, and Hydraulic Fluids and Lubrication Systems** .

550-6.7 WARNING PLATE

550-6.7.1 A warning plate similar to that shown in Figure 550-6-1 shall be posted in all liquid oxygen areas.

550-6.8 SAFETY PRECAUTIONS-GASEOUS OXYGEN

550-6.8.1 Heed the following precautions when working with or around gaseous oxygen:

a. Never use compressed oxygen for cooling the body or for blowing dust from clothing.

b. Never lubricate any part of a gaseous oxygen system that is in contact with oxygen. Use of approved thread compounds (e.g., for threaded valve bonnets) is permitted. Use compounds sparingly.

c. Always bleed pressure from the system before breaking gaseous oxygen connections.

d. Maintain strict cleanliness in handling all oxygen systems.

e. Ensure that no combustible materials are used in gaseous oxygen systems. Approved materials for transfer of gaseous oxygen are copper, nickel-copper, and copper-nickel.

f. Keep sparks and open flames away from all oxygen generating, storage, pumping, and vaporizing equipment.

Prohibit smoking, painting, welding, cutting, fueling, battery charging, and ammunition handling within 50 feet of liquid oxygen transfer or gaseous oxygen charging operations.

g. Keep all combustible materials away from possible contact with oxygen. Contamination of organic material (e.g., dirt, dust, soap, grease, oil, cloth, paper, wood, cork, carbon black, and gasoline) with oxygen creates an explosion hazard when the materials are subjected to shock or ignition.

h. Do not vent oxygen into a closed compartment. Ensure that adequate ventilation is established where venting is permitted.

i. During submarine oxygen replenishment operations, isolate rather than ventilate compartments containing oxygen manifolds. These compartments may be ventilated only if ventilation will not require that the access to the adjacent compartment be open.

j. Never remain in an oxygen-rich atmosphere. Personnel breathing an excess of oxygen may experience dizziness, numbness, or mental confusion. These conditions will correct themselves without after effects once the normal balance of carbon dioxide in the blood is restored. Adequate ventilation will prevent this hazard.

k. Strictly comply with all cleanliness requirements in any operation involving gaseous oxygen. Keep all facilities, tools, protective equipment, and clothing free from grease, oil, rags, wood, metal chips, or other foreign materials during the entire transfer operation.

l. Have station personnel serve as remote operators for oxygen bank stop valves whenever these valves are open during loading and unloading operations.

m. Fly the Bravo Flag while loading or offloading oxygen.

n. Fight class A, B, and C fires developing within an oxygen-enriched atmosphere (OEA) at a distance with applicable shipboard firefighting methods and agents: water, aqueous film-forming foam (AFFF), Purple-K-Powder, i.e., potassium bicarbonate dry powder (PKP), mechanical (liquid) foam, carbon dioxide, or halogenated hydrocarbon such as Halon 1301. Use handlines with seawater or AFFF, as appropriate. Avoid exposure to an oxygen-enriched atmosphere. In such an atmosphere, clothing will burn rapidly when ignited. An oxygen-enriched atmosphere presents the hazards of accelerated combustion and the likelihood that fast-spreading flames can totally involve a compartment or confined space.

NOTE

Of the extinguishing agents aboard ship, carbon dioxide is the least preferred for fighting fires in an oxygen-enriched atmosphere.

HAZARDS

1. Contact of liquid oxygen with the skin causes frostbite and burns.
2. Mixing oxygen with fuels creates a serious explosion hazard. Frozen fuel liquid oxygen mixtures are extremely shock sensitive.
3. Gaseous oxygen vaporizing from liquid oxygen can be absorbed in clothing; ignition from any source may cause flare-burning of clothing.

FIRST AID

1. Flush affected areas with water.
2. Call for medical attention.

SAFETY PRECAUTIONS

1. Be familiar with the nature and characteristics of liquid and gaseous oxygen.
2. If engaged in liquid oxygen handling or transfer operations, wear approved goggles or face shields, protective clothing, gloves, and boots. Wear clothing free from grease and oil.
3. When performing operations involving the handling of liquid oxygen, work in groups of two or more.
4. Exercise extreme caution to prevent any oils, greases, fuels, or combustible materials from coming in contact with liquid oxygen. Degrease all tools and metals before putting them into liquid oxygen service.
5. Take care to prevent accumulation of moisture in lines, valves, and traps in order to avoid freezing, plugging, and subsequent pressure ruptures. Also take care to prevent entrapment of liquid oxygen in unvented sections of the system.
6. Inspect safety showers and personnel protective equipment periodically and prior to any operations involving transfer of liquid oxygen that might result in spillage.

WARNING

Oxygen can be entrained in clothing. A spark or red hot object can initiate violent burning.

7. Upon leaving liquid oxygen storage or handling areas, ensure that no oxygen remains absorbed in clothing before smoking or approaching sources of ignition. This should be accomplished by either changing clothing worn in storage or handling areas or allowing a period of 15 minutes for clothing to ventilate sufficiently.

Figure 550-6-1. Safety Instructions for Personnel Assigned to Liquid Oxygen Area.

550-6.9 SUBMARINE OXYGEN GENERATORS

550-6.9.1 Additional safety precautions for submarine oxygen generators are given in the applicable technical manuals:

NAVSEA 0923-LP-000-8010, **Electrolytic Oxygen Generator, Model 6L16, Volume 1** .

NAVSEA S9515-C-MMM-010, **Generator, Electrolytic Oxygen, Model 7L16, Volume II** .

SECTION 7.
SHIPBOARD GAS PIPING SYSTEMS

550-7.1 PURPOSE

550-7.1.1 Shipboard gas piping systems are provided for the distribution of oxygen, nitrogen, carbon dioxide, helium, helium oxygen mixtures and inert gases. These distribution systems support aviators' breathing equipment, submarine atmosphere replenishment, diving systems, inerting systems, accumulator pressurization, and other services as set forth herein.

550-7.1.2 Characteristics of gases used onboard ship are given in Section 1. Safety precautions related to these gases are given throughout this section and in Section 6. For definitions of terminology used in this section, see Appendix A.

550-7.2 OXYGEN SYSTEMS FOR AVIATION SUPPORT

550-7.2.1 GENERAL. Aircraft carriers are provided with two oxygen-nitrogen plants, one forward and one aft. The oxygen-nitrogen producer in each plant is capable of producing liquid oxygen of high purity. The liquid oxygen is piped to a storage tank by means of an insulated or double-walled transfer line.

550-7.2.2 LIQUID OXYGEN. Liquid oxygen is stored in vacuum jacketed tanks ranging from 750 to 1,500 gallons in storage capacity. Each tank has an additional 10 percent vapor space. The storage tanks are located in each oxygen-nitrogen plant. Liquid oxygen is transferred out of the tank through a special valve connected to a flexible metal hose. The liquid oxygen travels through the valve and hose to a 50-gallon liquid oxygen mobile transfer cart. Relief valves are installed on those systems where liquid oxygen can be trapped between closed valves. These valves prevent excessive pressure buildup caused by vaporization of the liquid oxygen.

550-7.2.3 GASEOUS OXYGEN. Each oxygen-nitrogen plant is equipped with a liquid oxygen pump and a liquid oxygen vaporizer. The low-pressure liquid oxygen from the storage tank is pumped at high pressure to the liquid oxygen vaporizer. Gaseous oxygen is piped from the vaporizer via a manifold to a 10-cubic foot storage flask located in the oxygen-nitrogen plant space. From the storage flask, the gaseous oxygen is further piped to a charging station. The charging station is enclosed within a locker located on the hangar bay bulkhead adjacent to each oxygen-nitrogen plant. Gaseous oxygen is supplied at the required pressure by means of a pressure reducing valve, or needle valve, and charging hose. Pressurized oxygen is used for charging aircraft bail-out bottles, seat pans, oxygen cart cylinders, and cylinders for other shipboard use, such as industrial use in shops and in medical spaces. While in use for charging equipment, the needle valve must be manned at all times to ensure against overpressurization. The locker contains a main shut-off valve, supply pressure gage, a 3,000/1,800

lb/in^2 reducer valve with upstream and downstream shutoff valves, a needle valve bypass, discharge pressure gage, vent valve, automatic shut-off valve, hose connection, and a 15-foot charging hose with hose storage rack.

550-7.3 OXYGEN SYSTEMS FOR SUBMARINE SUPPORT

550-7.3.1 LIQUID OXYGEN. Submarine tenders are equipped with one oxygen-nitrogen plant capable of producing high-purity liquid oxygen. The liquid oxygen is stored in a 1,500-gallon tank located in the oxygen-nitrogen plant room. On submarine tenders, the liquid oxygen is used primarily for producing gaseous oxygen for shipboard use and for submarine replenishment.

550-7.3.2 GASEOUS OXYGEN. The oxygen-nitrogen plant is provided with a liquid oxygen pump and a liquid oxygen vaporizer for producing gaseous oxygen from the stored liquid oxygen. Low-pressure liquid oxygen from the storage tank is pumped at high pressure to the liquid oxygen vaporizer.

550-7.3.2.1 Gaseous oxygen at pressures up to 3,200 lb/in^2 is discharged from the vaporizer to a 10-cubic-foot flask in the plant space. The pressure reducing control panel in the oxygen-nitrogen plant has a 3,000/50 lb/in^2 reducing manifold. The manifold provides 50 lb/in^2 oxygen gas to the liquid oxygen storage tank for emergency pressurization of the tank to facilitate overboard dumping of the tank contents. Gaseous oxygen is supplied from the distribution control panel at a nominal pressure of 3,000 lb/in^2 to the following:

a. Four charging outlets, two port and two starboard, each within a stowage locker, for charging submarine oxygen banks to 3,100 lb/in^2 . The receiving ship's banks are charged to a higher pressure than the normal storage pressure of 3,000 lb/in^2 . The higher pressure compensates for pressure reduction that occurs during cooling of the gas on completion of the charge.

b. A charging outlet with a 3,000/1,800 lb/in^2 reducer, located within a stowage locker, for filling portable oxygen cylinders.

550-7.4 OXYGEN SYSTEMS FOR DIVING SUPPORT

550-7.4.1 FUNCTION. Gaseous oxygen is used in divers' breathing gas for the following purposes:

a. Decompression and treatment of divers in decompression chambers, in the water by means of umbilicals (mixed-gas dive only), and in saturation bells (personnel transfer capsules-PTC's).

b. Primary breathing medium in certain models of self-contained, underwater breathing apparatus.

c. With helium in mixtures of varying proportions for surface-supplie d (using umbilicals) mixed-gas, deep-sea diving operations.

d. To provide metabolic oxygen required for chamber and PTC environments during saturation diving operations.

550-7.4.2 COMPONENTS. Oxygen systems used for different purposes vary considerably in complexity and overall system configuration. The basic oxygen system is usually comprised of certain standard components. Paragraphs 550-7.4.2.1 through 550-7.4.2.4 identify these components.

550-7.4.2.1 Aviators' Breathing Oxygen. Only aviators' breathing oxygen in accordance with MIL-0-27210 is acceptable for use as divers' breathing gas. Gaseous oxygen, as prescribed in MIL-0-27210, shall contain not less than 99 percent oxygen by volume with remaining impurities as stated therein.

550-7.4.2.2 Stowage Containers. There are two primary means of oxygen stowage in U.S. Navy diving systems:

a. Cylinders manufactured in accordance with MIL-C-15111.

b. Flasks manufactured in accordance with MIL-F-22606.

550-7.4.2.2.1 Stow oxygen containers only in designated, well-ventilated spaces. If equipment is available, conduct an atmospheric analysis before entry into a sealed compartment where oxygen is stowed. Work in teams of two if equipment is not available and entry into a confined space containing oxygen is required. Station one person immediately outside the space while the other is inside.

550-7.4.2.3 Piping and Fittings. Oxygen system piping and fittings shall comply with MIL-STD-777.

550-7.4.2.4 Transfer Equipment. In diving-related operations, it is necessary to transfer oxygen to various locations. During transfer, it is necessary to control oxygen flow and pressure. In U.S. Navy diving systems, there are three primary means of controlling the transfer of oxygen.

a. **Cascade** - The use of oxygen piped from high-pressure gas banks through a pressure reducer to supply required flow rate and pressure at various outlet stations.

b. **Oil-free transfer pumps and compressors** - The use of nonlubricated transfer pumps and compressors as booster pumps to top off flask pressure and to transfer oxygen between flasks.

c. **Mixmaker** - The use of a gasmixing console to mix various gases needed for diving operations. The mixmaker uses helium and oxygen from the ship's gas banks and combines the gases in desired percentages for stowage or immediate use.

550-7.5 OXYGEN SYSTEM CLEANING

550-7.5.1 GENERAL. Both in-place oxygen piping systems and individual components shall be cleaned as required by and in accordance with MIL-STD-1330. Certification of systems and components shall be in accordance with MIL-STD-1630. Changes, modifications, and additions to procedures outlined in MIL-STD-1330 and MIL-STD-1630 shall have prior NAVSEA approval.

550-7.6 OXYGEN CHARGING

550-7.6.1 OFFICER IN CHARGE. The Commanding Officer shall designate, in addition to the Duty Officer, an officer in charge of the oxygen-charging operation. Satisfactory completion of a formal qualification checkoff is required prior to designation as a qualified Oxygen Charging Officer or a qualified Oxygen Charging Petty Officer.

550-7.6.1.1 The officer in charge is responsible for ensuring that:

a. All combustible materials within 50 feet of the charging connections are removed; No Smoking signs are posted prominently around the charging connection; all weather deck openings within 50 feet of the charging station are closed and all ventilation intakes in the area are secure.

b. Adequate illumination is provided for night charging operations.

c. The word is passed to prohibit smoking, battery charging, painting, hot work, fueling, and ammunition handling onboard during charging operations. This message is repeated at least every 15 minutes during the charge.

d. A Bravo Flag is flown while loading or offloading oxygen.

e. All facilities, tools, protective equipment, and clothing are free of grease, oil, rags, wood, metal chips, and other foreign materials during the entire transfer operation.

f. Approved firefighting agents are readily available.

g. All unauthorized personnel are excluded from roped-off areas; trainees under instruction have proper authorization and supervision.

h. The proper sound-powered telephone communication is set up between all oxygen-charging personnel and the Oxygen Charging Officer.

i. Oxygen leak detection and monitoring instruments are accurately calibrated and properly operated and are located in the vicinity of the manifolds, flasks, and cylinder stowage compartments.

j. Equipment, tools, and instruments are properly distributed to authorized oxygen-charging personnel. Only nonspark-producing tools (pipe-wrench NSN 5120-00-264-5207; monkey- wrench NSN 5120-00-288-8504) are to be used for connecting and disconnecting oxygen transfer lines.

k. A pre-operation briefing is held between all shipboard oxygen charging personnel and dockside commercial or military/tender oxygen-charging personnel. Shipboard oxygen charging personnel should include all duty section supervisory personnel, a watchstander directly affected by the evolution, and the ship's corpsman. All disagreements over equipment, precautions, or procedures are resolved prior to beginning charging operations.

l. All ships in the berth or moored on the pier are notified of pending oxygen-charging operations and are again notified when oxygen charging has been secured.

m. All requirements of the local area commander are complied with in full and reported to the Commanding Officer of the ship receiving the charge.

n. The charging line assembly and the ship's portable oxygen charging line and end connections are visually inspected to ensure that polyethylene bags are not torn, end connections are not contaminated, and tags are affixed. If bags have been torn or otherwise appear to be contaminated, the charging line must be re-cleaned as outlined in paragraph 550-7.5.

o. The ship's oxygen system is lined up to receive oxygen in accordance with the ship's instructions for oxygen charging.

550-7.6.2 PRELIMINARY PROCEDURE Prior to oxygen charging operations:

1. Vent the ship's charging connection by means of charging connection bleed valve and verify by gage or by the following disassembly procedure:
   a. Back off or loosen the cap union nut not more than one full turn.

b. With the union nut loose, test the cap to ensure that it is loose. If the cap is loose, indicating that it is depressurized, complete the disassembly. If the cap is not loose, assume that there is pressure under the cap.

c. If the cap continues to remain tight, back off the union nut an additional one-half turn. Again, test the cap to determine whether or not it is loose.

d. Do not complete the disassembly until the cap is depressurized.

e. Keep the cap in a clean polyethylene bag.

2. Connect the flexible charging line to the ship's charging connection and to the charging source. Use new VITON A O-rings in accordance with MIL-R-83248, type I, class I. For the oxygen charging line, use a Teflon-lined hose assembly, consisting of hose and fittings (in accordance with MIL-H-83298, MIL-H-83296, and MIL-H-38360 respectively) for service at pressures to 3,000 lb/in^2 . A suitable hose is the Aeroquip AE206 rated at 3,000 lb/in^2 working pressure and 12,000 lb/in^2 minimum burst pressure, available in sizes 4 through 10. For services at pressures up to 5,000 lb/in^2 , use as a charging line a Teflon lined hose similar to Aeroquip AQ678 bulletin MEB/31.

3. Secure the oxygen-charging connection bleed valve after the proper installation of the charging line assembly.

4. Take sample oxygen readings within designated areas, using the issued portable or fixed oxygen analyzer. The oxygen system should not leak at all. The purpose of the monitoring is to detect minor leakage. If leakage is detected, secure charging operation, isolate the leak, and take further action as directed by the Commanding Officer.

5. Pressure test and leak check the charging line as follows:

a. Instruct the charging unit crew to build up the pressure gradually in the charging line to 500 lb/in^2 while maintaining a continuous leak test. Using a leak detection solution in accordance with MIL-L-25567, test all threaded connections that were made up during the on-site rigging of the charging line assembly.

b. If no leaks are indicated, continue building up the pressure in 500 lb/in^2 increments until 75 percent of the system's rated pressure is reached.

c. If a leak is observed at any time, secure the charging source, bleed the line, and repair the leak. Maintain system cleanliness during repair.

d. Continue building pressure and repeat test for leaks (as outlined in step 5a., above) using 200 lb/in^2 increments from 75 percent of the system's rated pressure to the final charge pressure. Hold 15 minutes and leak check.

e. Bleed the charging line pressure down to about 25 lb/in^2 above the residual pressure of the system to be charged, regardless of system pressure.

550-7.6.3 CHARGING PROCEDURE. After the charging line assembly has been leak checked, pressure tested, and bled down to 25 lb/in^2 above the residual system pressure, proceed with the charging procedure.

1. Slowly open backup stop valves for the banks to be charged. This will equalize pressure between banks. If banks are equalized too rapidly, freezing of the equalizer lines may result.

2. Slowly open the charging valve to equalize pressure between the banks and the charging line.

3. Instruct the off-hull charging operator to begin charging operations.

4. If necessary, use the system's oxygen transfer pump in order to top off the oxygen flasks to sufficient pressure. Follow specific ship's instructions and operating procedures.

5. Frequently monitor the oxygen-analyzing equipment. With every 200 lb/in^2 of increase in bank pressure, check for leaks by using a leak detector solution (in accordance with MIL-L-25567) on threaded charging connections.
6. When the pressure in the banks reaches the required level, notify the charging unit's operator to secure charging operations.
7. Secure the ship's charging valve.
8. Secure the backup valves for the charged banks.
9. Slowly open the ship's charging line vent valve and bleed down the charging line to atmospheric pressure.
10. Ensure that caps to be replaced on the charging connection are oxygen-cleaned in accordance with MIL-STD-1330.
11. Disconnect the charging line, install the union caps, and seal the ends in polyethylene bags to prevent the entry of foreign matter. Cap the charging stations (with new Viton A O-rings) and install enclosures.
12. Purge the flexible charging line with oil-free nitrogen (in accordance with BB-N-411), bag end connections in polyethylene bags and re-stow in accordance with MIL-STD-1330.

550-7.6.4 SPECIFIC CHARGING PROCEDURES BY SHIP TYPE. There are special valve lineups and unique requirements for different classes of ships.

550-7.6.4.1 ASR 21 Class. For specific valve lineup and unique requirements for ASR 21 class ships, see NAVSEA S9594-AC-OPI-010, **Deep Diving System, MK 2 MOD 1 Operating Procedures on Ship's Gas System Valve Lineup and Oxygen Charging** . Review the individual command's shipboard instructions on charging.

550-7.6.4.2 ATS 1 Class. For specific valve lineup and unique requirements for ATS 1 class, see NAVSEA SS520-AJ-MMO-010, **Diving System** . Review the individual command's shipboard instruction on charging.

550-7.6.5 USS ELK RIVER (IX-501). For specific valve lineup and unique requirements for USS ELK RIVER (IX-501), see NAVSEA SS500-AE-PRO-020, **Submarine Development Group One Deep Diving System (DDS) MK 2 MOD 0 Operating Procedures** . Review the individual command's shipboard instruction on charging.

550-7.7 NITROGEN SYSTEMS FOR AVIATION SUPPORT

550-7.7.1 GENERAL. In addition to liquid oxygen, the oxygen-nitrogen plants in aircraft carrier nitrogen systems produce both liquid and gaseous nitrogen of high purity (see paragraph 550-7.2.1). They provide this nitrogen to the carriers' nitrogen distribution systems from their respective distribution panels. Reducing valves are installed in supply lines to provide the required pressure at each equipment inlet connection. The 5,000 lb/in^2 and the 3,500 lb/in^2 gaseous nitrogen piping mains from the forward and aft oxygen-nitrogen plants are cross-connected.

550-7.7.2 LIQUID NITROGEN. Each oxygen-nitrogen plant has a liquid nitrogen storage tank ranging from 300 to 1,500 gallons in capacity with a 10 percent vapor space. The storage tank has a valved connection to enable filling Dewar flasks for plant maintenance freeze-scaling operations and for filling liquid nitrogen servicing units.

550-7.7.3 GASEOUS NITROGEN. Each oxygen-nitrogen plant includes a liquid nitrogen pump and a liquid nitrogen vaporizer. Low-pressure liquid nitrogen from the storage tank is discharged as a high-pressure liquid by the pump and is then converted to a gas by the vaporizer. The vaporizer discharges gaseous nitrogen at 5,000 lb/in^2 via a manifold to gaseous nitrogen flasks. The flasks supply nitrogen to the plant distribution panel, where its pressure can be reduced from 5,000 lb/in^2 to 3,500, 2,000, and 50 lb/in^2 for distribution throughout the ship.

550-7.7.3.1 Gaseous nitrogen at 5,000 lb/in^2 is supplied for the following services:

a. AQM-37A checkout area station

b. Tire and wheel shop

c. Nitrogen launcher bottle charging and stowage station

d. Aircraft weapons checkout rooms

e. Missile testing facilities

550-7.7.3.2 Gaseous nitrogen at 3,500 lb/in^2 is provided for:

a. Servicing unit charging stations

b. MK 4 gun pod magazine and assembly area

c. MK 4 gun pod shop

550-7.7.3.3 All nitrogen servicing unit charging stations have a warning plate inscribed with the available pressure, e.g., **Warning - 3,500 lb/in^2 nitrogen** .

550-7.7.3.4 Gaseous nitrogen at 2,000 lb/in^2 is supplied to two nitrogen cylinder charging stations. These stations are located outside each oxygen-nitrogen plant in the hangar bay. They are provided with warning plates inscribed **WARNING - 2,000 lb/in^2 GASEOUS NITROGEN-ONLY CHARGE CYLINDERS WITH 2,000 lb/in^2 PRESSURE RATING** . Portable 2,000 lb/in^2 nitrogen cylinders are installed in the anchor windlass machinery room, in special weapons magazines, and in radar rooms.

550-7.7.3.5 Gaseous nitrogen at 50 lb/in^2 is supplied for purging liquid oxygen mobile charging carts, pressurizing liquid nitrogen storage tanks, inerting boilers during layup, and for use in the photo laboratory.

550-7.8 TENDER NITROGEN SYSTEMS FOR SUBMARINE SUPPORT

550-7.8.1 GENERAL. The oxygen-nitrogen plant onboard each tender produces liquid and gaseous nitrogen of high purity for shipboard use and for submarine replenishment.

550-7.8.2 LIQUID NITROGEN. The liquid nitrogen is stored in a 1,500-gallon tank located in the plant room. On submarine tenders the liquid nitrogen is used primarily for producing gaseous nitrogen and filling Dewar flasks for plant maintenance freeze-scaling operations.

550-7.8.3 GASEOUS NITROGEN. The oxygen-nitrogen plant has a liquid nitrogen pump and a liquid nitrogen vaporizer installed. These produce high-pressure gaseous nitrogen for shipboard use and for submarine replenishment. The nitrogen is dispensed from two charging outlets, one port and one starboard, installed on the 01 level.

550-7.8.3.1 High pressure gaseous nitrogen, at 5,000 lb/in^2 , is discharged from the vaporizer and stored in a 10-cubic-foot flask located in the oxygen-nitrogen plant. The flask supplies nitrogen to the distribution control panel where the pressure can be reduced to 3,000, 1,800, and 50 lb/in^2 and distributed throughout the ship.

550-7.9 NITROGEN INERTING SYSTEMS

550-7.9.1 Gaseous nitrogen is used for preventing and extinguishing fires to protect automotive gasoline (Mogas) systems aboard amphibious support ships. Nitrogen gas inerting systems onboard ship are described in **NSTM Chapter 542, Gasoline and JP-5 Fuel Systems** .

550-7.10 CARBON DIOXIDE INERTING SYSTEMS (MOGAS SYSTEMS)

550-7.10.1 On some ships, a carbon dioxide inerting system consisting of carbon dioxide cylinder stowage and transfer piping is provided. This system is used to inert the automotive gasoline cofferdam, the automotive gasoline storage tank, and the gasoline filling and fueling system. The system also provides for the blow-back of the automotive gasoline hose. For typical Mogas system piping arrangement, see Figure 550-7-1.

550-7.10.2 A number of carbon dioxide cylinders complying with Fed Spec RR-C-901 are installed in the carbon dioxide inerting cylinder room. The carbon dioxide cylinders for this system are not fitted with internal siphon tubes.

550-7.10.3 The carbon dioxide cylinders are manifolded to discharge through a 2,000/300 lb/in^2 reducing valve to an expansion tank with a 4-cubic-foot volume. The expansion tank discharges successively through a 300/100 lb/in^2 reducing valve, a 100/10 lb/in^2 reducing valve, and 10/4 lb/in^2 reducing valve to a distribution manifold that discharges through tailpipes to the cofferdam and tank.

550-7.10.4 The low-pressure side of each reducing valve (2,000/300, 300/100, 100/10, and 10/4 lb/in^2) is fitted with a relief valve set at 336, 112, 15, and 7 lb/in^2 respectively. Pressure gages are provided on the high-pressure side of the 2,000/300 lb/in^2 reducing valve, on the expansion tank, and on the low-pressure side of each reducing valve. Each reducing valve is fitted with isolation valves. A bypass with a needle valve is provided around the isolation valves of each reducing valve. The relief valve outlets are joined in a common vent line leading to the weather on the main deck.

550-7.10.5 The carbon dioxide supply lines are provided with manually-controlled cutout valves at the cofferdam boundaries. The piping within the cofferdam has a number of branches, arranged for proper diffusion of the gas. The branches terminate in baffle-type diffusion heads located about one-third of the tank height above the tank bottom. Means are provided for venting the charging lines when the system is secured.

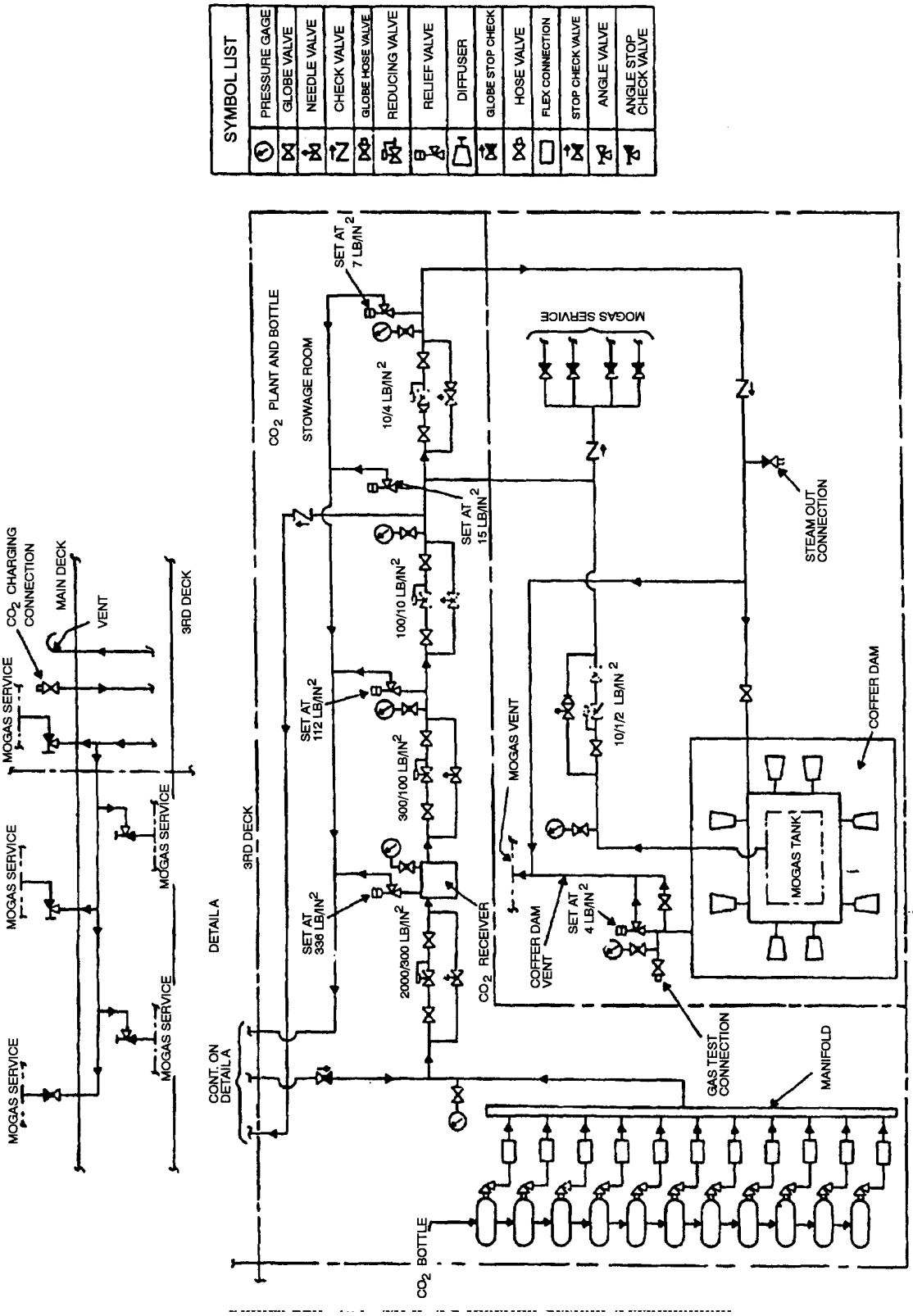

Figure 550-7-1. MOGAS Inerting System Arrangement

550-7.10.6 Vent connections are provided at the top of cofferdams for purging with the minimum loss of carbon dioxide. The vent connections have cutout valves installed at the cofferdam boundaries. A pressure gage, a relief valve set at 4 lb/in^2 , and a gas sampling connection are provided on the cofferdam side of each vent cutout valve. The relief valve discharges to the downstream side of the vent cutout valves. The red-hand indicator of the pressure gage located at the control panel is set at the 8-ounce mark.

550-7.10.7 Two portable inertness analyzers and connection fittings are provided to indicate the percent inertness of the automotive gasoline cofferdam. The inertness analyzers are described in **NSTM Chapter 542, Gasoline and JP-5 Fuel Systems** .

550-7.10.8 A steaming-out connection is provided on the carbon dioxide supply line to and in gas-freeing the cofferdam. A check valve is provided in the carbon dioxide supply line to prevent steam or gasoline from backing up into the inerting system.

550-7.10.9 A shore charging connection for initially inerting the automotive gasoline cofferdam is provided. The shore connection consists of a stop valve located at an external location, close to the carbon dioxide bottle stowage. The shore charging station valve is connected to the discharge manifold of the carbon dioxide cylinders. A check valve is installed to prevent back flow to the shore charging station connection.

550-7.10.10 Normally the cofferdams are inerted while the ship is in a shipyard or another activity where sufficient carbon dioxide is available. Carbon dioxide is used until an inertness reading of 35 percent is reached on the inertness analyzer. The cofferdam, with the vent closed, is then pressurized to 8 ounces with additional carbon dioxide.

550-7.10.11 The number of carbon dioxide cylinders installed for pressurizing the cofferdam is sufficient to raise the pressure in the cofferdam to 0.5 lb/in^2 after the 35 percent inertness concentration has been obtained and to repeat the pressurization operation seven times.

550-7.10.12 Carbon dioxide supply to the gasoline tanks is taken from downstream of the 100/10 lb/in^2 reducing valve and reduced to 0.5 lb/in^2 through a 10/10.5 lb/in^2 reducing station. Pressure in the gasoline tank is controlled using the manual control valves provided at the tank boundary.

550-7.10.13 Gasoline tank carbon dioxide charging lines and vent lines are located on opposite ends of the tank.

550-7.10.14 Downstream from the tank, the automotive gasoline tank vent is provided with a test connection, a relief valve, and a cutout valve, in that order. The relief valve discharges into the tank vent downstream of the cutout valve. The relief valve is set to relieve at 4 lb/in^2 .

550-7.10.15 The automotive gasoline stowage tank vent is combined with the cofferdam tank vent at a point downstream from the relief valves. The combined vent terminates in a flameproof screen above the 04 level in the weather deck.

550-7.10.16 Carbon dioxide (CO_2) cylinders are installed for inerting and charging the gasoline tank. These cylinders are sufficient in number to raise the pressure in the empty gasoline tank to 0.5 lb/in^2 , then repeat the inerting and pressurization operation three times.

550-7.10.17 A warning plate is installed at the gasoline pump stating **OPEN CO_2 CHARGING LINE PRIOR TO STARTING PUMP AND CLOSE AFTER PUMP IS SECURED** .

550-7.10.18 Carbon dioxide is also provided for purging and charging the gasoline delivery lines. The carbon dioxide is supplied to a point immediately above the lowest valve in the gasoline suction piping, to a point between the gasoline filter discharge and the filter automatic shutoff valve, and to the bypass lines around the filter. The carbon dioxide for the gasoline delivery lines is supplied from the downstream side of the 100/10 lb/in^2 reducing valve and the 15 lb/in^2 relief valve. This ensures that the carbon dioxide is at 10 lb/in^2 for purging the gasoline lines and protects the delivery system from pressure excess of 15 lb/in^2 . A bypass line around the 100/10 lb/in^2 reducing valve supplies carbon dioxide in the event of reducing valve failure. A check valve installed in the carbon dioxide supply line prevents the entrance of gasoline by accidental operation of the cutout valve at the gasoline main. A sufficient number of carbon dioxide cylinders are provided to purge and charge the gasoline piping system 12 times.

550-7.11 INSPECTION AND CHANGING OF CYLINDERS IN CARBON DIOXIDE BANKS

550-7.11.1 Semiannually, inspect carbon dioxide cylinders for external bulges, cracks, dents, and corrosion. Inspect associated flexible hoses for cracks, fraying, and other signs of deterioration.

550-7.11.2 Use the carbon dioxide cylinders until the bank pressure drops below 90 percent of the vapor pressure corresponding to the carbon dioxide temperature as given in Table 550-7-1. When the cylinder pressure drops below 90 percent of the vapor pressure, the liquid carbon dioxide in the cylinder has been used up and the cylinder is to be considered empty.

550-7.11.3 The gas temperature may be based on the ambient space temperature or determined by use of a contact thermometer. When changing cylinders in the bank, comply with cylinder handling procedures outlined in paragraph 550-2.10.

550-7.12 CARBON DIOXIDE FIREFIGHTING SYSTEMS

550-7.12.1 For firefighting systems, see **NSTM Chapter 555, Volume 1, Surface Ship Firefighting** .

550-7.13 INERT GAS SYSTEMS

550-7.13.1 For added information on inert gas systems used to inert gasoline systems, see **NSTM Chapter 542, Gasoline and JP-5 Fuel Systems** .

550-7.14 HELIUM AND HELIUM-OXYGEN SYSTEMS FOR DIVING SUPPORT

550-7.14.1 FUNCTION. Gaseous helium and helium-oxygen mixtures are used as a constituent of divers' breathing gas. Requirements for the use of oxygen systems are the same as for the handling and use of all helium-oxygen mixtures. Helium and helium-oxygen systems should comply with all recommendations in paragraph 550-7.4. Helium is used in diving systems in the following ways:

a. In varying percentages in mixtures used as divers' breathing gas during mixed-gas deep diving operations, or in treatment, decompression, and saturation deep-diving operations.

b. In the pressurization of chamber and personnel transfer capsule for deep-sea saturation diving.

Table 550-7-1. VAPOR PRESSURE - TEMPERATURE CORRELATION

Carbon Dioxide Temperature (°Fahrenheit)	Vapor Pressure (Pounds Per Square Inch Gage)	90 Percent Vapor Pressure (Pounds Per Square Inch Gage)
40	550	495
50	635	570
60	730	650
70	835	750
80	960	860
90	1,190	1,070
100	1,450	1,305
110	1,710	1,540

550-7.14.2 COMPONENTS. Helium systems vary considerably in complexity and overall system configuration, depending upon the diving purpose for which they are used (see paragraph 550-7.14.1). There are certain standard components that comprise the basic helium system for most U.S. Navy diving systems. These components are identified in paragraphs 550-7.14.2.1 through 550-7.14.2.4.

550-7.14.2.1 Pure Helium. Respirable helium, type I, grade B, is pure enough for use as divers' breathing gas. MIL-P-27407 is used as the procurement specification. Respirable helium shall contain not less than 99.99 percent pure helium by volume with the remaining impurities as stated in MIL-P-27407.

550-7.14.2.2 Stowage Containers. There are two primary means of helium storage in U.S. Navy diving systems:

a. Cylinders manufactured in accordance with MIL-C-15111.

b. Flasks manufactured in accordance with MIL-F-22606.

550-7.14.2.2.1 Before entering any confined space where helium is stowed, conduct an atmospheric analysis to determine if sufficient oxygen is present to support life.

550-7.14.2.3 Piping and Fittings. All helium system piping and fittings shall be constructed in accordance with MIL-STD-777, **Schedule of Piping Valves, Fittings, and Associated Piping Components for Naval Surface Ships** .

550-7.14.2.4 Transfer Equipment. In diving-related operations, it is necessary to transfer helium to various locations. During helium transfer, it is important to control the flow. In U.S. Navy diving systems, there are three primary means of controlling the transfer of helium:

a. **Cascade** - The use of helium piped from high pressure gas banks through a pressure reducer to supply required flow rate and pressure at the various outlet stations.

b. **Oil-free transfer pumps and compressors** - The use of transfer pumps and compressors as booster pumps to top off flask pressures and to transfer helium between flasks.

c. **Mixmaker** - The use of a gas mixing console to combine various oxygen-helium gas mixtures needed for diving operations. The mixmaker uses helium and oxygen from the ship's gas banks and combines the gases in desired percentages for stowage or immediate use.

550-7.15 HELIUM SYSTEM CLEANING

550-7.15.1 Cleaning procedures must be performed on both in place helium piping systems and individual components. The approved system cleaning procedure is outlined in a NAVSEA Industrial Support Office (NISO) publication, SK-STD-2036118, **Divers Life Support Systems Cleaning and Testing Procedure for Oxygen, Mixed Gas and Air (in Excess of 1,000 PSI) Systems** . Any change or modification to this cleaning procedure or the development of additional cleaning procedures shall be submitted to Commander, Naval Sea Systems Command (NAVSEA OOC) for approval prior to issuance.

550-7.15.2 If inspection indicates that any major portion of the system does not require cleaning, this section shall be isolated and not cleaned. Unnecessary cleaning of outboard flasks and piping, in particular, is to be avoided. If flasks are not provided with openings at both ends, continuous circulation of the cleaning compound is not possible.

550-7.16 GENERAL HELIUM CHARGING PROCEDURES

550-7.16.1 OFFICER IN CHARGE. The Commanding Officer shall designate, in addition to the duty officer, an officer in charge of the charging operation. Satisfactory completion of a formal qualification checkoff shall be required prior to designation as a qualified Helium Charging Officer or as a qualified Helium Charging Petty Officer.

550-7.16.1.1 The officer in charge is responsible for ensuring that:

a. All weather deck openings within 50 feet of the charging station are closed and all ventilation intakes in the area are secured.

b. Adequate illumination is provided for night charging operations.

c. The word is passed, in advance, to stand clear of the helium charging operation and is repeated at least every 15 minutes during the charge.

d. All facilities, tools, protective equipment, and clothing are free from grease, oil, rags, wood, metal chips, and other foreign materials during the entire transfer operation.

e. Approved firefighting agents are readily available.

f. All unauthorized personnel are excluded from roped-off areas; trainees under instruction have proper authorization and supervision.

g. The proper sound-powered telephone communication is set up between all helium-charging participating personnel and the Helium Charging Officer.

h. Oxygen monitoring instruments and helium leak detectors are accurately calibrated and properly operated and are located in the vicinity of all manifolds and flask and cylinder stowage compartments.

i. Equipment and tools are properly distributed.

j. A preoperation briefing is conducted between all shipboard helium-charging personnel and dockside commercial or military/tender helium-charging personnel; all disagreements over equipment, precautions, or procedures are resolved prior to beginning charging operations.

k. All ships in the berth or moored at the pier are notified of pending helium-charging operations and when charging has been secured.

l. All requirements of the local area commander are complied with in full and reported to the Commanding Officer of the ship receiving the charge.

m. The charging line assembly and the ship's portable helium charging line and connections are visually inspected to ensure that the polyethylene bags are not torn, the end connections are not contaminated, and the (certified oxygen clean) tags are affixed. If the bags have been torn or otherwise appear to be contaminated, the charging line must be cleaned (see paragraph 550-7.20.2).

n. The ship's helium system is lined up to receive helium in accordance with ship's instruction for helium charging.

550-7.16.2 PRELIMINARY PROCEDURE. Prior to helium charging operation, leak check, pressure test, and pressure bleed the charging line assembly as follows:

1. Vent the ship's charging connection via the charging connection bleed valve and verify by gage or the following disassembly procedure.
   a. Back off or loosen the cap union nut not more than one full turn.
   b. With the union nut loose, test the cap to ensure that it is loose. If the cap is loose, indicating that it is depressurized, complete the disassembly. If the cap is not loose, assume that there is pressure under the cap.
   c. If the cap continues to remain tight, back off the union nut an additional one-half turn. Again test the cap to determine whether or not it is loose.
   d. Do not complete the disassembly until the cap is depressurized.
   e. Keep the cap in a clean polyethylene bag.
2. Connect the flexible charging line to the ship's charging connection and to the charging source. If applicable, use new Viton A O-rings in accordance with MIL-R-83248, type I, class 1, Federal Supply Class 5330. For the charging line use a Teflon-lined hose in accordance with paragraph 550-7.6.2, step 2.
3. Secure the helium-charging connection bleed valve after the proper installation of the charging line assembly.
4. Take sample oxygen readings within designated areas using the issued portable or fixed oxygen analyzers and helium leak detectors. The helium system should not leak at all. The purpose of the monitoring is to detect minor leakage. If leakage is detected, secure the charging operation, isolate the leak, and take further action as directed by the Commanding Officer.
5. Pressure test and leak check the charging lines as follows.
   a. Instruct the charging unit crew to build charging line pressure gradually to 500 lb/in^2 while maintaining a continuous leak test. Leak test all threaded connections that were made up during the onsite rigging of the charging line assembly. (Use a leak detector solution in accordance with MIL-L-25567 to ensure a tight charging system.)
   b. If no leaks are indicated, continue the procedure outlined in step 5.a. above. Increase pressure in 500 lb/in^2 increments until 75 percent of the system's rated pressure is reached.

c. If a leak is observed at any time, secure the charging source, bleed the line, and repair the leak. Maintain system cleanliness during repair.

d. Continue building pressure while testing for leaks. Use 200 lb/in^2 increments from 75 percent of the system's rated pressure to the final charge pressure. Hold 15 minutes and leak check.

e. Bleed the charging line pressure down to about 25 lb/in^2 above the residual pressure of the system to be charged, regardless of system pressure.

550-7.16.3 CHARGING PROCEDURE. After the charging line assembly has been leak checked, pressure tested, bled down to 25 lb/in^2 - above the residual system pressure or 100 lb/in^2 - whichever is less, proceed with the charging operation.

1. To equalize pressure between banks, slowly open backup stop valves for the banks to be charged. If banks are equalized too rapidly, freezing of the equalizer lines may result.
2. Slowly open the charging valve to equalize pressure between the banks and the charging line.
3. Instruct the off-hull charging operator to begin charging operations.
4. If necessary, use the system's helium transfer pumps in order to top off the helium flasks to sufficient pressure. Follow specific ship's instructions and operating procedures.
5. Frequently monitor the oxygen analyzing and helium leak detection equipment. Every 200 lb/in^2 of bank pressure, check for leaks by using a leak detector solution in accordance with MIL-L-25567 on threaded charging connections.
6. When the pressure in the banks reaches the required level, notify the charging unit's operator to secure charging operations.
7. Secure the ship's charging valve.
8. Secure the backup valves for the charged banks.
9. Slowly open the ship's charging line vent valves and bleed down the charging line to atmospheric pressure.
10. Ensure that the caps to be replaced on the charging connections are oxygen cleaned in accordance with MIL-STD-1330.
11. Disconnect the charging line, install the union caps, and seal the ends in polyethylene bags to prevent entry of foreign matter. Cap the charging station (with new Viton A O-rings) and install enclosures.

550-7.16.4 UNIQUE CHARGING PROCEDURES BY SHIP TYPE. There are special valve lineups and unique requirements for different ship classes.

550-7.16.4.1 ASR 21 Class. For specific valve lineup and unique requirements for ASR 21 class ships, see NAVSEA S9594AC-OPI-010, **Deep Diving System MK 2 MOD 1 Operating Procedures on Ships' Gas System Valve and Helium Charging** . Review the individual command's shipboard instruction on charging.

550-7.16.4.2 ATS 1 Class. For specific valve lineup and unique requirements for ATS 1 class, see NAVSEA SS520-AJ-MMO-010, **Diving System** . Review the individual command's shipboard instruction on charging.

550-7.16.4.3 USS ELK RIVER (IX-501). For specific valve lineup and unique requirements for USS ELK RIVER (IX-501), see NAVSEA SS500-AE-PRO-020, **Submarine Development Group One Deep Diving System (DDS) MK 2 MOD 0 Operating Procedures** . Review the individual command's shipboard instruction on charging.

550-7.17 SUBMARINE OXYGEN SYSTEMS

550-7.17.1 FUNCTION. The oxygen system on submarines revitalizes the ship's atmosphere by replacing the oxygen consumed by the ship's personnel. It maintains acceptable levels of oxygen in the ship's atmosphere, permitting unrestricted support of human life for an extended period.

550-7.17.2 DESCRIPTION. On SSBN class, SSN 637 class, and later submarines, electrolytic oxygen generators provide oxygen to revitalize the ship's atmosphere during submerged operations. On the SSBNs, two generators are operated at approximately 60 percent capacity, while on the SSNs a single generator is operated at approximately 100 percent capacity. The generators normally operate at an internal pressure of 3,000 lb/in^2 . They discharge to the oxygen main through a normally open oxygen generator isolation valve, an oxygen aftercooler, a moisture-separator flask, and a normally open oxygen main isolation valve.

550-7.17.2.1 The oxygen main pressure will be variable up to 3,000 lb/in^2 . A pressure relief valve, between the oxygen generator isolation valve and the aftercooler, is set at 3,360 lb/in^2 to protect the piping from overpressure. The oxygen discharged from the generator is cooled by the aftercooler from approximately 37.8°C (100°F) to 18.3°C (65°F) before it reaches the oxygen main. Chilled water is the cooling medium. The moisture-separator removes any moisture and electrolyte carried over by the oxygen discharged from the generator. The separator is drained to a moisture collecting tank through an isolation valve and a needle valve.

550-7.17.2.2 The oxygen main runs the length of the ship. It carries oxygen from the generators to the forward and aft reducing stations and oxygen storage banks.

550-7.17.2.3 Oxygen pressure-reducing stations reduce the 3,000 lb/in^2 g oxygen to approximately 10-15 lb/in^2 g. The stations discharge the oxygen through a flow meter and an oxygen diffuser to the submarine atmosphere. Flow can be adjusted to provide the required flow rate at approximately 1 cubic foot per hour per crew member. The diffuser mixes air with the oxygen. The discharge is located near a ventilation discharge terminal to obtain atmospheric mixing. One of the reducing stations can also supply oxygen to the ship's resuscitator through a locked shut valve and hose connection.

550-7.17.2.4 Emergency oxygen supplies are available to the forward and after halves of the ship from oxygen banks located in the main ballast tanks that are connected to the oxygen main.

550-7.17.2.5 When one of the two oxygen generators is not capable of generating oxygen, the other generator is operated at full power. This ensures that oxygen is always supplied to the ship's atmosphere at the required nominal rate. An oxygen candle furnace is installed as an additional standby for supplying oxygen. The onboard supply of oxygen candles is sufficient to support the normal complement of personnel for 3 to 5 days.

550-7.17.3 STORAGE. Oxygen for the standby replenishment system is stored in banks. The oxygen banks store and supply a sufficient amount of oxygen to sustain the crew for a specified number of days.

550-7.17.3.1 The bank flasks are located externally in the main ballast tanks and are connected to the oxygen main through bank hull and back-up valves. The banks can be charged from an offhull source through a charging connection (generally located in the forward escape trunk), a lift check valve, the oxygen main, and the bank's backup and hull valves. A locked-closed bypass is provided across the check valve for use during the offloading of oxygen from the bank. The banks are normally replenished by the ship's oxygen generators.

550-7.17.3.2 On SSNs that predate the 637 class and that have no generators, oxygen is stored at 3,000 lb/in^2 in flasks located in the ballast tanks. System operation is similar to that described for ships with generators.

550-7.18 SUBMARINE NITROGEN SYSTEMS

550-7.18.1 Nitrogen systems are provided for oxygen generator purge and portable flask charging. On SSBN submarines, they are used for missile service as well. Generally a single shore connection is provided to load and offload all nitrogen banks.

550-7.18.2 A nitrogen bank at 4,500 lb/in^2 is provided for oxygen generator purge and portable flask charging. For purging the oxygen generator, the pressure is reduced to 3,000, 1,800, or 900 lb/in^2 depending on the purge system valving and piping and the number of transfer barriers. This bank can also supply the missile nitrogen system, but nitrogen from the missile system cannot be used for oxygen generator purge.

550-7.19 SUBMARINE MISSILE GAS SYSTEM

550-7.19.1 FUNCTION. The missile gas (MG) service system on SSBN submarines performs the prelaunch functions of missile tube inerting, prepressurization, and bias control. After a surface launch, the system is used for tube purging.

550-7.19.2 STORAGE AND DISTRIBUTION. Nitrogen for the missile gas system is stored at 4,500 lb/in^2 g. The storage system is divided into several cross-connected port and starboard flask banks. Nitrogen supplied to the missile tubes is generally reduced to a pressure of 145 lb/in^2 .

550-7.19.3 PIPING SYSTEMS. A high-pressure air connection installed upstream of the missile gas pressure reducing stations provides air as a backup for the nitrogen. This air is also used for training in missile tube prepressurization and bias control. The missile gas system pressure reducers are always on the line. Gas (either air or nitrogen, as selected) from these reducers is fed into the main header, serving the missile tubes. It is also provided to each tube for prelaunch pressurization and bias control.

550-7.20 SUBMARINE OXYGEN CHARGING

550-7.20.1 CHARGING LINE PREPARATION. A charging line assembly of sufficient length, but as short as feasible, shall be prepared. Either of two charging line assemblies are available for submarine tender use. One assembly is made up from annealed copper tubing and requires annealing facilities in order to maintain the assembly in an annealed condition. The other assembly uses a combination of flexible metal hoses and Monel pipe. For dockside charging, use only the annealed copper charging line assembly. Use the flexible metal hose for dockside charging only when specifically approved by NAVSEA. Prepare the charging line assembly as described in paragraphs 550-7.20.1.1 through 550-7.20.1.2.2.

550-7.20.1.1 Annealed Copper Charging Line. Use the required length of annealed copper tubing (0.840-inch outside diameter and 0.220-inch wall thickness NSN 9C-4710-278-2209) in accordance with MIL-T-24107. Use silver brazing couplings (NSN 9C-4730-203-0114) in accordance with NAVSHIPS dwg 8101385941. Provide the submarine charging end with a bronze silver brazing union thread piece in accordance with NAVSHIP dwg 810-1385943. Attach a suitable silver brazing adapter on the other end. The adapter will be used for connecting the charging line assembly to the tender's oxygen charging station or the dockside charging outlet. The entire charging line assembly is silver brazed so that the only threaded connections are at each end terminal. Silver braze and inspect the charging line in accordance with NAVSEA 0900-LP-001-7000, **Fabrication and Inspection of Brazed Piping Systems** .

550-7.20.1.2 Flexible Metal Hose Charging Line. Use the required lengths of Monel pipe and two or three lengths of flexible metal hose. The 8-1/2-foot-long sections of flexible metal hose (NSN 9C-4720-289-4615) shall be in accordance with MIL-H-17666. Thoroughly clean the hose externally and internally before assembly. Use a long-handled brush as required for internal cleaning. Clean as directed by MIL-STD-1330, **Cleaning and Testing of Oxygen and Nitrogen Gas Piping Systems** . Use the Monel pipe that is schedule 80, 0.840-inch outside diameter, 0.147-inch wall thickness in accordance with MIL-T-1368, **Federal Supply Classification 4710** . Connect lengths of pipe with Monel couplings, schedule 80 or 3,000 lb/in^2 in accordance with ANSI B16.11.

550-7.20.1.2.1 Assemble the flexible metal hose charging line from the following pieces (see Figure 550-7-2).

a. A suitable adapter using O-rings for connecting the flexible metal hose to the oxygen charging station outlets on the tender

b. The first length of flexible metal hose

c. A suitable adapter to connect the flexible metal hose to the Monel pipe

d. A length of Monel pipe

e. A pipe to hose adapter

f. A length of flexible metal hose located in the center of the charging line

g. A hose to pipe adapter

h. A length of Monel pipe

i. A pipe to hose adapter

j. A length of flexible metal hose

k. A suitable adapter, using O-rings to connect the flexible metal hose to the submarine portable charging line. The end piece shall be a union thread piece in accordance with NAVSHIPS dwg 810-1385943.

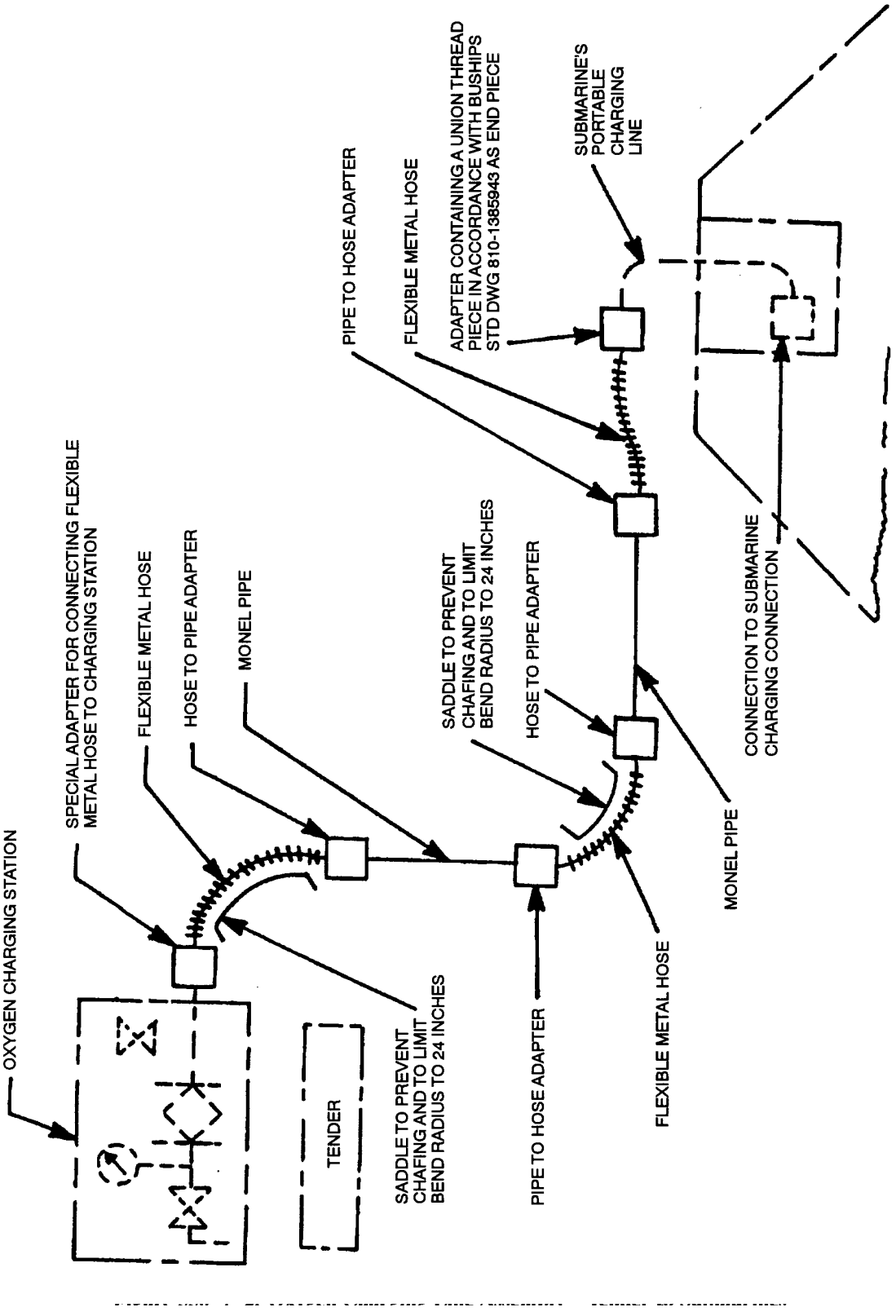

Figure 550-7-2. Oxygen Charging Line Assembly - Tender to Submarines

550-7.20.1.2.2 Weld and inspect the charging line in accordance with MIL-STD-278.

550-7.20.2 CHARGING LINE CARE AND MAINTENANCE. After it is fabricated, clean, test, and stow the charging line in accordance with requirements in MIL-STD-1330. Hydrostatically test the charging line assembly as required by MIL-STD-1330.

550-7.20.2.1 When the charging line is in use, support the line from the tender in such a manner that it is not placed on or supported by the flexible metal hose sections.

550-7.20.2.2 Replace Teflon O-rings for union-ended charging fittings and union-ended valves prior to each charging operation. Teflon O-rings are available from the following sources:

- C.E. Conover and Co., Fairfield, NJ 07006, Tel: 800-631-4149, (210) 227-6900
- Greene Rubber, Cambridge, MA 02142, Tel: (617) 547-7655
- I.B. Moore, Cambridge, MA 02142, Tel: 800-343-5280, (617) 491-0100
- Nyantic Rubber, Cranston, RI 02910, Tel: (401) 942-0900
- Chemplast Inc., Wayne, NJ 07470, Tel: 800-526-7844, (201) 696-4700

For Walseal-type fittings, fabricate seals from tube, sheet, or rod polytetrafluoroethylene material in accordance with MIL-R-8791.

550-7.20.2.3 Reanneal the annealed copper charging line after the line has been uncoiled and recoiled six times. Reanneal after the line has been used six times for charging operations or whenever the line is suspected of being work-hardened as a result of ship movement, handling, or other reasons. Anneal by heating in a furnace 427°C, 4 ±28° (800°F, ±50°) for 1 hour. The line shall then be air cooled until it returns to ambient temperature.

550-7.20.2.4 After annealing the charging line, reclean and retest the line in accordance with MIL-STD-1330. Cap, bag, and tag the end fittings as specified in paragraph 550-7.20.2.

550-7.20.3 CHARGING LINE VENT. When any portion of the system to be charged is below 500 lb/in^2 gage, a valved vent line is required downstream of the shore or tender charging connection. The vent must be a 1/2-inch nominal pipe size (NPS) line, approximately 20 feet high, with a 0 to 5,000 lb/in^2 gage and gage cutout valve. Attach the vent to the charging line with a union connection through a tee and adapters. Use Teflon O-ring seals or attach to the charging station bleed connection. Use two Teflon-packed, nonferrous metal valves in series for venting.

550-7.20.3.1 When the initial system pressure is 500 lb/in^2 or above, the use of the vent line feature is not required.

550-7.20.4 DOCK PREPARATION. When oxygen is to be transferred from the shore, prepare the dock as follows:

1. Take extreme care to prevent liquid oxygen from spilling or dripping upon asphalt, wood, oil-covered concrete, or any other combustible material. If charging units or trucks have provisions for preventing such conditions it is not necessary to prepare the area over which the unit is to be positioned. If provision for spillage

or dripping is not incorporated in the charging unit or truck design, position the pump section of the unit over a 6- to 8-inch layer of clean crusted rock, confined in a 10-inch deep unpainted, corrosion-resistant steel tray or trays. To catch any liquid that may spill, ensure that the assembled tray is 3 feet longer and wider than the charging unit. Provide a ramp to permit the unit to enter and leave the bed of crushed rock.

2. Rope off the area within a 50-foot radius of the charging unit and the area through which the charging line passes. Clear the area of all vehicles, cranes, and other equipment that are not required during oxygen-charging operations. Remove all combustibles and prominently display No Smoking signs around the perimeter of the roped-off area.
3. Provide adequate illumination for the entire charging area during night charging operations.
4. Prohibit hot work, smoking, battery charging, painting, fueling, or ammunition handling onboard during charging operations.
5. Have a manned fire engine standing by during the operation. Use only approved firefighting agents for fighting oxygen-enriched fires.
6. Do not start a charging operation during an electrical storm. If an electrical storm occurs while a charging operation is in progress, subsequent action is at the discretion of the officer in charge. The officer in charge must decide either to continue or stop the charging operation, taking into account all factors affecting safety of the operation.
7. Ensure that the submarine to be charged is single berthed during the charging operation. If single-berthing facilities are unavailable, berth the submarine being charged so that it is the ship that is nearest the dock. Inform outboard ships that the charge is in progress.

550-7.20.5 COMMERCIAL SOURCE PREPARATION. When a commercial oxygen source is used, the officer in charge of the charging operation and the oxygen supplier's representative shall inspect the overall system. They must mutually determine if charging can safely proceed. No charging shall be permitted until areas of disagreement over precautions or procedures are resolved.

550-7.20.5.1 For oxygen charging from commercial oxygen sources, the following preparations apply:

1. The submarine shall inform the charging unit how much oxygen gas (in standard cubic feet) is required to recharge its banks. Standard cubic feet may be converted to gallons of liquid oxygen by dividing by 115. Fill the liquid oxygen charging unit tank with an adequate amount to ensure completion of the charge. Conduct the filling operation in an open area clear of combustible materials. Pressurize the supply tank to a pressure sufficient to deliver liquid oxygen to the charging tank.
2. Connect to a shore power connection on the pier for any electrical power requirements.
3. Securely attach a static electric ground connection from the charging unit to the submarine being charged. Use a similar connection to ground the unit to metal piping attached to the dock.
4. If charging unit design permits, purge and pressure test the pump and vaporizer with dry, oil-free nitrogen (in accordance with BB-N-411). Start cooldown of the equipment in accordance with manufacturer's instructions.
5. Ensure that all safety devices are activated and in working order. Verify the correct shutdown pressure switch setting of the charging unit, commercial or tender.
6. Connect a cylinder of dry, oil-free nitrogen (in accordance with BB-N-411) to the charging line bleed connection for purging the charging line prior to use. See paragraph 550-7.20.8.

7. Upon request from the submarine to be charged, provide up to three Beckman oxygen analyzers in current calibration.

550-7.20.6 SUBMARINE TENDER PREPARATION. Prepare a submarine tender for an oxygen charging operation as follows:

1. Remove all combustible material within 50 feet of the charging connection and post No Smoking signs prominently around this area on the main deck. Close all weather deck openings within 50 feet of the charging connection and secure ventilation intakes in that area.
2. Provide adequate illumination for night charging operations.
3. Prohibit smoking, battery charging, painting, hot work, fueling and ammunition handling onboard during charging operations.
4. Ensure the ready availability of approved firefighting agents.
5. Ensure that all pumping unit safety devices are activated and in working order.
6. Ensure that the storage tank contains an adequate quantity to complete a charge. The submarine shall inform the tender of the quantity of gaseous oxygen required to recharge its banks. The quantity of oxygen in standard cubic feet may be converted to gallons by dividing by 115.
7. Connect an oil-free nitrogen (in accordance with BB-N-411) source to the charging line bleed connection for purging the charging line prior to use. See paragraph 550-7.20.8.
8. Start pump cool-down in accordance with manufacturer's instructions.
9. Upon request from the submarine to be charged, provide up to three Beckman oxygen analyzers.
10. The submarine to be charged should be single moored alongside the tender during charging operations. If single mooring is impractical, the submarine to be charged should be moored nearest the tender and the outboard ships informed when the oxygen charge is in progress.

550-7.20.7 SUBMARINE PREPARATION. Prepare a submarine for an oxygen charging operation as follows:

NOTE

Twenty-four hours prior to charging operations, equalize all banks to be charged that have a common manifold. (This applies to older installations.)

1. The Commanding Officer shall designate, in addition to the duty officer, an officer in charge of the oxygen charging operation. Satisfactory completion of a formal qualification checkoff shall be required prior to designation as a qualified Oxygen Charging Officer or a qualified Oxygen Charging Petty Officer.
2. The Officer in Charge is responsible for ensuring that:
   a. The following areas are roped-off and posted: areas in the immediate vicinity of each oxygen manifold, valve grouping, or mechanical connections to be assembled, operated, tested, inspected, or monitored during the oxygen charging operation.
   b. Personnel designated Oxygen Charging Petty Officers are thoroughly trained, fully qualified, and officially authorized.

c. Roped-off areas and corresponding duties are assigned to the designated and authorized Oxygen Charging Petty Officers.

d. All unauthorized personnel are excluded from the roped-off areas. Trainees under instruction should have proper authorization.

e. The proper sound-powered telephone communication has been set up between all oxygen charging personnel and the Officer in Charge.

f. A portable blower is properly set up topside (upwind of the escape trunk as far as practicable) with a discharge hose extending to the bottom of the escape trunk.

g. The oxygen leak detection or monitoring instruments are accurately calibrated and properly operated.

h. Equipment, tools, and instruments are properly distributed to the authorized oxygen charging personnel. Use only nonspark-producing tools for all connecting and disconnecting operations (i.e., NSN 5120-264-5207 pipe wrench and NSN 5210-288-8504 monkey wrench).

i. The word is passed that the smoking lamp is out throughout the ship prior to commencing the charging operation and is repeated at least every 15 minutes during the charge.

j. The starting and stopping of electrical equipment is prohibited within the roped-off areas and in any other areas designated by the Commanding Officer, except as specifically authorized by the Commanding Officer or Officer in Charge of the oxygen charging operation.

k. Proper certification is received from the cognizant dockside and tender oxygen charging personnel to the effect that the charging line assembly meets all the requirements listed in this section.

l. The charging line assembly and the ship's portable oxygen charging line end connections have been visually inspected to ensure that the liquid oxygen polyethylene bags have not been torn, that the end connections are not contaminated, and that (certified oxygen clean) tags are affixed.

m. The submarine charging connection is properly vented by way of the charging connection bleed valve prior to the removal of the charging connection cap. The disassembly procedure for the charging connection cap shall be as follows:

   (1) Back off or loosen the 2-inch union nut not more than one full turn.

   (2) With the union nut loose, test the cap to ensure that the cap is loose. If the cap is loose, indicating that it is depressurized, complete the disassembly procedure. If the cap is not loose, assume that there is pressure under the cap.

   (3) If the cap continues to remain light, back off the 2-inch union nut an additional one half turn. Again test the cap to determine whether or not it is loose.

   (4) Do not complete the disassembly until the cap is depressurized.

n. The ship's portable charging line fittings have the proper Teflon O-rings in place and are satisfactorily made up light to the mating charging connection on the submarine and to the charging line from the oxygen source.

o. The oxygen charging connection bleed valve is short after the proper installation of the charging line assembly.

p. All bank hull stop valves and gage stop valves are opened.

q. All bank hull back-up valves are in the secured shut position.

r. Prior to the oxygen charging operation, sample oxygen readings are taken within the areas designated, using the issued NAVSEA approved portable oxygen analyzers. The purpose of the monitoring is to detect minor leakage. There should be no leaks in the oxygen system. If leakage is detected, secure the charging operation, isolate the leak, and take further action as directed by the Commanding Officer.

s. Ventilation fans serving affected compartments are operated in fast speed.

t. Ventilation fans serving affected areas may only be secured while checking for oxygen leaks if the venti-

lation is interfering with accurate leak detection. This may be necessary if ventilation air is discharging directly into the area being surveyed, potentially diluting an oxygen leak to an undetectable level. Ventilation should be restored after the leak survey has been completed.

u. Watertight doors of compartments containing oxygen manifolds, valves, and valve groupings under charge are shut and dogged. Watertight doors which are shut and dogged shall have a caution tag posted indicating that the compartment contains a potentially hazardous atmosphere and permission is required from the oxygen charging officer for entry. Compartments containing oxygen manifolds, valves and valve groupings must be isolated rather than ventilated if ventilation would require that the access to the adjacent compartment be open. Each command must determine which bulkhead flappers require shutting for additional securing during the charge. Doors and hatches not specifically required to be shut should be inspected to ensure that they are clear for closure. Obtain the Commanding Officer's permission if any doors or hatches must remain open during the charge. If access through closed watertight doors is required for watch relief or for watch standers' inspection, such access should be minimized and controlled on a case basis by the Officer in Charge.

v. The bottom escape trunk hatch cover is kept open.

w. On all submarines, the topside escape trunk hatch cover shall be kept open.

NOTE

Submarines with a high-pressure main between forward and after banks may be charged from either the forward or after charging connection, as desired. The safety precautions listed above, except for smoking lamp which is out throughout the ship, apply only to the compartment in which the charging line is connected to the system. Charging and bleed valves at the opposite end of the ship shall be secured and the charging connection capped.

550-7.20.8 LINE ASSEMBLY PURGE AND PRESSURE TEST. Immediately prior to charging, purge and pressure test the oxygen charging line.

1. Purge the charging line assembly with dry, oil-free nitrogen (in accordance with BB-N-411) from the tender's nitrogen connection or from a cylinder connected to the dock side charging unit's vaporizer bleed connection.
2. Purge and pressure test the oxygen charging line assembly as follows:
   a. Ensure that the stop valve in the submarine charging line check valve bypass is locked closed and that the submarine charging valve is secured.
   b. Rig the charging line assembly and the ship's portable charging line into place and make up threaded end connections on the tender or on the dockside charging unit and on the submarine.
   c. Purge the complete charging line assembly through the submarine's charging connection bleed valve for 5 minutes.
   d. Gradually build up pressure in the charging line to 500 lb/in^2 while maintaining a continuous leak test. Using a leak detector solution in accordance with MIL-L-25567, test all threaded connections made up during the onside rigging of the charging line assembly.
   e. If no leaks are indicated, continue to raise the pressure in 500 lb/in^2 increments, checking for leaks as outlined in step d. above. Stop when pressure reaches 2,500 lb/in^2 .
   f. If a leak is observed at any time, secure the nitrogen source, bleed the line, and repair the leak. Maintain system cleanliness during repair.
   g. Repeat the procedure outlined in steps c. through f. above, until a pressure of 2,500 lb/in^2 is obtained with

no leaks. If nitrogen at a higher pressure is available, continue test for leaks (as outlined in step d.) every 200 lb/in^2 increment until a pressure of 3,100 lb/in^2 is reached.

h. Bleed the pressure in the charging line down to about 25 lb/in^2 above the residual pressure of the system to be charged, regardless of system pressure.

550-7.20.9 CHARGING PROCEDURE. After the charging line assembly has been properly connected, purged with dry, oil free nitrogen (in accordance with BB-N-411), and pressure tested, proceed with the charging operation.

1. Ensure that all submarine oxygen manifold valves are lined up as follows:
   a. Hull stops open
   b. Gage stops open
   c. Backup stops shut
   d. Reducing station stops shut
   e. Charging connection bleed valves shut
   f. Charging line's check valve bypass valve shut and locked
   g. Charging valve shut.
2. Slowly open backup stop valves for the banks to be charged to equalize pressure between banks. If banks are equalized too rapidly, freezing of the equalizer lines may result.
3. Slowly open the charging valve to equalize pressure between the banks and the charging line.
4. If the submarine oxygen bank to be charged has a residual system pressure below 500 lb/in^2 g, monitor and maintain below 500 lb/in^2 the differential pressure between the submarine's most distant bank gages and the tender's weatherdeck charging station gage or the shore-based charging facility gage. Until the submarine's bank pressure reaches a minimum of 500 lb/in^2 , maintain this differential pressure either by using vent valves provided in the 20-foot vertical vent line to bleed off excess flow or by controlling the speed of the shore-based charging unit pump.
5. Instruct the off-hull charging operator to commence charging operation.

WARNING

Carryover of liquid oxygen into the charging line and submarine system is extremely hazardous and must be prevented.

6. Start the charging equipment and maintain storage tank pressure at the level required by the pump suction; maintain constant surveillance of the vaporizer outlet gas discharge temperature indicator to ensure proper temperature control. If the vaporizer discharge gas temperature falls rapidly, secure the charging pump immediately. Determine the cause of vaporizer malfunction and correct the problem before restarting the charging equipment.
7. Charge banks to 3,100 lb/in^2 (maximum). The pressure switch settings on the charging unit may require adjustment as necessary to ensure that the submarine's banks are fully charged.
8. When the pressure in the bank has reached 3,100 lb/in^2 , notify the charging unit's operator to secure the liquid oxygen pump.
9. After the liquid oxygen pump has been secured, shut the back-up valves for the charged tanks.

10. Repeat steps 2, 4, 5, 6, 7, 8, and 9 until the banks at each manifold are charged.
11. During the entire time that the charging line is pressurized with oxygen, check with NAVSEA approved portable oxygen analyzers for pockets of oxygen in the vicinity of the manifold and in the escape trunk. Have the oxygen charging petty officer report portable oxygen analyzer readings every 15 minutes to the charging officer topside.
12. During charging, soap test or leak test the charging line threaded connections at every 200 lb/in^2 increase of bank pressure, or every 10 minutes if the charging pressure exceeds the initial test pressure of the charging ring. Do not conduct soap tests on the threaded joint charging connection located within the escape trunk. Check for changes in the oxygen concentration in the trunk by taking readings with the NAVSEA approved portable oxygen analyzer's sample tube. Insert the sample tube into the escape trunk as opposed to physically climbing into the trunk.
13. Under the following conditions, secure the charging operation immediately.
    a. Oxygen concentration as noted on the NAVSEA approved portable oxygen analyzer reaches 24 percent in the escape trunk or charging room.
    b. Any leaks are noted.
    c. There is external icing of the charging line.
    d. The charging pump or charging unit malfunctions.
    e. Any other abnormal condition is found.

550-7.20.10 SECURING AFTER COMPLETION OF CHARGE. When the banks are at 3,100 lb/in^2 , secure the liquid oxygen pump and vaporizer.

550-7.20.10.1 Secure submarine's shipboard system as follows:

NOTE

The normal position of oxygen bank hull stop valves shall be OPEN for all ships equipped with remote closure capabilities. The normal position of oxygen bank hull stop valves shall be SHUT for all ships not equipped with remote closure capabilities, except when bleeding from bank.

1. Check that all backup stop valves and the charging valve are shut.
2. Vent the charging line to atmospheric pressure by using the bleed valve at the tender's weather deck charging station or at the vaporizer on the off-hull charging unit. As an alternative, vent the charging line through the elevated vent pipe.
3. Disconnect the charging line; install union blinds or caps and seal ends in polyethylene bags to prevent entry of foreign matter. Cap the charging connection and install enclosure. Purge the submarine's portable charging line with dry oil-free nitrogen (in accordance with BB-N-411), install union blinds at each end, seal the ends in polyethylene bags to prevent entry of foreign matter and restow the line aboard the submarine.
4. Ventilate the escape trunk with the topside portable blower until oxygen concentrations, as indicated on a portable oxygen analyzer, are lower than 22 percent.
5. Ventilate compartments containing manifolds, valves, and valve groupings used during the charging operation.

Ventilate each compartment for at least 30 minutes while checking the entire compartment with a NAVSEA approved portable oxygen analyzer. Continue to ventilate until oxygen concentrations are less than 22 percent in all locations.

6. After at least 30 minutes of ventilating and when oxygen concentration is less than 22 percent, restore watertight doors and the escape trunk hatch to their normal material condition of readiness and restore ventilation to its normal operation mode.

550-7.20.10.2 Secure off-hull charging equipment as follows.

NOTE

If any of the steps are not applicable to the equipment, secure the charging equipment in accordance with the manufacturer's instruction book (base instructions and applicable safety precautions).

1. After the pump has been secured, shut tank pressure buildup and charging pump inlet valves.
2. Open the pump high- and low-pressure bleed valves slightly to relieve pressure in the pump and vaporizer and permit liquid contained within the system to vaporize.
3. Open the storage tank vent valve slowly to relieve tank pressure. Leave the vent valve open after atmospheric pressure has been reached.
4. Follow equipment technical manual instructions for warming the pump and, if required, for purging the pump prior to completely securing system.
5. Disconnect charging line, cap the vaporizer discharge connection, purge the charging line with dry oil-free nitrogen (in accordance with BB-N-411), cap the ends of the charging line and seal ends in polyethylene bags. Remove line to storage and ensure the integrity of the end coverings.
6. Remove all restrictions imposed by paragraphs 550-7.20.4 through 550-7.20.9.

550-7.21 SUBMARINE OXYGEN OFFLOADING

550-7.21.1 PREPARATIONS AND CRITERIA FOR OXYGEN OFFLOADING. In order to minimize risks to the submarine, neighboring ships, shore installations, and personnel during industrial, maintenance, or repair periods (IMR), requirements for advance oxygen system preparations vary according to the type and location of needed submarine repairs. Required preparations for conditions A, B, and C, and the criteria upon which they are based, are as follows.

550-7.21.1.1 Condition A - No Offloading Required. In condition A, a surfaced submarine approaches a repair facility for an IMR with all onboard repairs limited to zero hot work.

550-7.21.1.1.1 Prepare in advance for condition A as follows:

1. Secure, purge, and isolate oxygen generator(s), if installed, in accordance with the manufacturer's instructions manual.

2. Secure and tag hull stops, gage stops, and bank backup stop valves for all oxygen banks.
3. Ventilation fans serving affected compartments should be operated in fast speed while accomplishing steps 4 and 5 below.
4. While bleeding down the oxygen piping, constantly monitor and check oxygen concentration in compartments, using at least two NAVSEA approved portable oxygen analyzers.
5. Slowly bleed oxygen distribution system bleed piping until the reducing station low-pressure gage reads about 50 lb/in^2 .
6. Monitor oxygen pressure gage reading at periodic intervals throughout the IMR.
7. Have the ship's Gas-Free Engineer/Damage Control Officer ensure that all advance preparations are completed and that the oxygen piping is, and remains, properly bled, as required, until termination of the IMR.

550-7.21.1.2 Condition B - No Offloading Required. In condition B, a surfaced submarine approaches the repair facility for an IMR with all onboard hot work repairs limited to the following areas:

a. Inside the pressure hull and in another compartment or at least 10 feet away from the oxygen bank cutout and backup valve area.
b. Outside of the pressure hull, or in a tank whose boundary is not adjacent to a ballast tank containing oxygen flasks or oxygen piping.

550-7.21.1.2.1 Prepare in advance for condition B as follows:

1. Complete all preparations required under condition A.
2. With repair facility assistance, use nitrogen (in accordance with BB-N-411) to purge (inert) and pressurize to 100 lb/in^2 all the internal oxygen distribution piping.
3. Have the ship's Gas-Free Engineer inspect and verify hot work areas in accordance with **NSTM Chapter 074, Volume 3, Gas Free Engineering** .

550-7.21.1.3 Condition C - Offloading Required. In condition C, a surfaced submarine approaches the repair facility for an IMR with onboard hot work repairs in an area other than those covered under condition B, such as:

a. In or on a boundary of a ballast tank containing oxygen flasks or oxygen piping. For example, if hot work repairs are to be done in a forward area not covered under condition B, then the forward oxygen banks must be offloaded, but not the after oxygen banks.
b. In the same compartment with, or within 10 feet of, the oxygen bank cutout and backup valve area.

550-7.21.1.3.1 Prepare in advance for condition C as follows:

1. Secure, purge, and isolate oxygen generator(s), if installed, in accordance with the manufacturer's instruction manual.
2. Offload oxygen banks in accordance with paragraph 550-7.21.2.1.

3. Purge (inert) and pressurize to 100 lb/in^2 all the oxygen piping and the offloaded banks, using nitrogen (in accordance with BB-N-411) and monitoring the inerted portions until termination of the IMR.

550-7.21.2 OXYGEN OFFLOADING PROCEDURE. An officer qualified for oxygen charging shall be directly in charge of the offloading operation. The Officer in Charge shall ensure that offloading takes place only when the vented oxygen can be piped downwind of submarines, tenders, and dock facilities.

550-7.21.2.1 Under the supervision of the Officer in Charge, offload oxygen downwind as follows.

NOTE

The offloading of oxygen by bleeding the bank through the normal onboard bleed connection is prohibited.

1. Hose down the topside of the submarine in the area of the charging connection to ensure that no grease, oil, or dirt is present in this vicinity.
2. Notify the tender or the base duty officer of the time that the oxygen bleed is expected to begin.
3. Request readiness of firefighting provisions on the tender or base.
4. Ensure that the offloading line is certified to meet all requirements with respect to material specifications and cleanliness listed herein. In addition, inspect the offloading line end connections to ensure that plastic bags have not been torn and ends have not become contaminated. (The offloading line may be either the charging line or another line assembly fabricated in accordance with paragraph 550-7.20.1 and used primarily for this operation.) Station personnel at the remote operator for oxygen bank stop valves whenever these valves are open for offloading.
5. Remove all flammable material from vicinity of the charging connection.
6. Secure all unnecessary electrical equipment in the escape trunk while offloading.
7. Shut and dog the bottom watertight escape hatch.
8. Check to ensure that all antennas have been deenergized.
9. Place a portable blower topside (upwind of the escape trunk as far as possible) with the discharge hose extending to the bottom of the trunk.
10. Establish sound-powered telephone communications between the compartment containing the oxygen manifold and topside.
11. Put the smoking lamp out throughout the ship. Pass the word at least every 15 minutes.
12. Ensure that all oxygen valves are lined up as follows:
    a. Hull and gage stops are open; and the backup stops, reducing station stops, and the charging valve are shut.
    b. Unlock and open the charging line check valve bypass stop valve.
    c. Open the charging connection bleed valves to slowly vent the piping up the charging connection; then shut the bleed valves.
13. Rig the offloading line to discharge downwind of all possible flammable material. Then secure the line to prevent the possibility of whipping.

14. Connect the ship's portable oxygen charging line to the charging connection; connect the offloading line to the portable line. Ensure that the fittings are properly made up.
15. Slowly open the charging valve.
16. Bleed down banks to 0 lb/in^2 only after thoroughly prepared to charge the system with dry oil-free nitrogen (in accordance with MIL-STD-1330) immediately upon reaching 0 lb/in^2 . Control the bleeding down by the individual bank backup stop valve.
17. Slowly open the backup stop valve to the first bank to be bled down and discharge the bank slowly to atmospheric pressure.
18. During the entire offloading operation, use portable Beckman oxygen analyzers to check for pockets of oxygen in the vicinity of the manifold and in the escape trunk. Oxygen readings should be continued during nitrogen charging as a means of detecting nitrogen leakage. Nitrogen leakage into the ship can present a personnel hazard and can be detected by decreasing oxygen concentration. Have the oxygen petty officer report the oxygen analyzer readings every 15 minutes to the Officer in Charge of offloading.
19. Slowly open the backup stop valve for the next bank to be bled down. (Not applicable to SS 563 class submarines.)
20. Repeat steps 17, 18, and 19 until all banks are bled down.
21. Secure the charging valve.
22. Check the escape trunk with a portable oxygen analyzer. Ventilate, if required, with a portable blower until a reading of less than 22 percent oxygen is obtained.
23. Disconnect the line used for offloading, purge with dry, oil-free nitrogen (in accordance with BB-N-411), install union blinds or caps at each end of the line, bag the end fittings, and store the line.
24. Immediately connect a supply of dry, oil-free nitrogen (in accordance with BB-N-411) to the charging connection. This connection may be made with oxygen-clean copper tubing rated for 100 lb/in^2 service. Approximately one standard nitrogen cylinder is required for each 24 cubic feet of oxygen storage capacity.
25. Slowly open the charging valve.
26. Slowly open the backup stop valve to the bank to be charged and charge the bank with nitrogen (in accordance with BB-N-411) to approximately 100 lb/in^2 .
27. When a 100 lb/in^2 pressure is obtained in the bank, secure the backup stop valve.
28. Repeat steps 26 and 27 until all banks are charged to 100 lb/in^2 with dry, oil-free nitrogen (in accordance with BB-N-411).
29. Secure the charging valve and bleed the nitrogen charging line to the atmospheric pressure, using the charging line bleed valve.
30. Disconnect the nitrogen supply from the charging connection.
31. Open the backup valves or the charging valve as required to bleed down each bank independently to 100 lb/in^2 if required. Maintain bank pressure at 100 lb/in^2 and periodically monitor.
32. With all banks at 100 lb/in^2 , secure the system as follows:
    a. Ensure that all oxygen valves are lined up as follows:
        (1) Hull stops open
        (2) Gage stops open
        (3) Backup stops shut

(4) Reducing station stops shut

(5) Charging connection bleed valve shut

b. Shut and lock the charging line's check valve bypass stop valve.

c. Cap the charging line and install the charging connection enclosure.

d. Install union blinds at each end of the portable charging line; seal ends in polyethylene bags and store line onboard.

33. Secure steps 2, 3, 5, 6, 7, 8, 9, 10, and 11, as applicable to return ship to normal condition.

550-7.22 SUBMARINE NITROGEN SYSTEM CHARGING

550-7.22.1 GENERAL. Authorized procedures for charging submarine nitrogen systems from tenders and dockside and for offloading submarine nitrogen storage and distribution systems are described herein. All applicable safety precautions in paragraph 550-1.4.7 and elsewhere in the chapter shall be observed during such operation. Requirements below pertain to replenishment of submarine nitrogen gas banks with oil-free nitrogen only. Nitrogen furnished and delivered by the gas supplier must meet the purity requirement of 99.5 percent as specified by Fed Spec BB-N-411. Tender-produced nitrogen shall have a minimum nitrogen purity of 99.5 percent for unrestricted use. (If purity of tender-produced nitrogen is less than 99.5 percent, charging shall be limited to the dedicated missile tube banks. A minimum nitrogen purity level of 97 percent is acceptable for missile gas service only.)

550-7.22.1.1 The Commanding Officer or Officer in Charge shall designate and formally certify trained personnel as authorized to operate nitrogen equipment or conduct or supervise the nitrogen transfer process. For personnel training requirements, see paragraph 550-6.3. Each ship or shore activity involved shall prepare detail procedures and checkoff sheets using the instructions given herein as a guide.

550-7.22.2 CHARGING LINE PREPARATION. Prepare the charging line required for submarine nitrogen system charging or offloading as follows:

1. Prepare a charging line of sufficient length, yet as short as feasible, using 25- or 50-foot lengths of hose. Use Aeroquip Corporation hose style 1529-6 or equivalent NAVSEA-approved hose that meets the following requirements.
   a. Diameter is 3/8 inch.
   b. End fittings are JIC-type Aeroquip figure 4721 on one end and 4725 on the other end. As an alternative, NAVSEA-approved fittings of other manufacturers are used.
   c. End fitting nipples are of Monel.
   d. Hose cover has fine perforations.
   e. Hose assembly has a minimum burst strength of 16,000 lb/in^2 . If a larger diameter hose is required, use Aeroquip 678-8 Teflon hose with JIC fittings. The part number for a hose assembly with reusable fittings is 678600-size-length and for a hose having permanently attached fittings, 735000-size-length.
2. Provide suitable adapters at each end of the assembled charging line to enable connecting the line to charging facility's end fitting and to the ship's portable charging line.
3. Hydrostatically test the assembled charging line to 7,500 lb/in^2 . Hold hydrostatic pressure for at least 5 minutes. Throughout testing, there must be no indication of leakage, weakness, or relative movement between the hose and end fittings. Annually, hydrostatically retest the nitrogen charging line assembly to ensure line integrity,

4. After each hydrostatic test, clean the charging line in accordance with the requirements of paragraph 550-7.25. Place end fittings in plastic bags after cleaning to prevent the entry of foreign matter. Reclean the charging line (in accordance with MIL-STD-1330) when there is reason to suspect that contamination has occurred during storage or in use.

550-7.22.3 SHORE AND TENDER CHARGING PREPARATION. Prior to nitrogen-charging operation, ensure that preparations in accordance with paragraphs 550-7.22.3.1 or 550-7.22.3.2 have been made ashore or on tender, as appropriate.

550-7.22.3.1 Commercial Charger. When a commercial nitrogen source will be used for a charging operation, ask the supplier for certification that the gas to be furnished is in accordance with Fed Spec BB-N-411. Ensure that nitrogen connections on the suppliers charging vehicle are cleaned in accordance with MIL-STD-1330 prior to connecting the charging line.

550-7.22.3.2 Naval Charging Units (Shore and Tender). When a naval charging unit (shore or tender) will be used, prepare for nitrogen charging as follows:

1. Ensure the availability of an adequate amount of liquid oil-free nitrogen of the required purity. Inform the tender or shore unit of the amount of nitrogen gas, in standard cubic feet (std ft^3), required to charge submarine banks. (Standard cubic feet can be converted to gallons of liquid nitrogen by dividing std ft^3 by 93.1.) If nitrogen has been purchased commercially, obtain the certification required in paragraph 550-7.22.3.1 above.
2. Purge pump and vaporizer and start cooldown in accordance with equipment manufacturer's instructions.
3. Ensure that all safety devices are activated, are in working order, and are set at the values required for the protection of the system to be charged.
4. For night charging operations, provide suitable illumination for the entire charging area.

550-7.22.4 SUBMARINE CHARGING PREPARATION. Prepare a submarine for a nitrogen charging operation as follows:

1. Assign an officer, in addition to the duty officer, to be in active charge of the nitrogen charging operation. Station the officer in charge in the vicinity of the charging unit or the operator.
2. Obtain certification from the tender or shore charging unit that the charging line meets all requirements given in paragraph 550-7.22.2.
3. Inform the charging unit operator that the submarine nitrogen banks require charging to 3,150 lb/in^2 or 4,750 lb/in^2 , as applicable. Check all corresponding nitrogen system protective device settings to ensure against system overpressurization.
4. Inspect the charging line end connections to ensure that the plastic bags have not been damaged and the ends have not become contaminated. If an end fitting is contaminated, clean in accordance with MIL-STD-1330.
5. Install submarine's portable nitrogen charging line to charging connection in submarine. Connect charging hose to the submarine's portable charging line. Use only new neoprene O-rings in making up charging line connections. Ensure that the charging hose has not been led over sharp projections nor subjected to sharp bends, especially at the end fittings.
6. Ensure that sound-powered phone communications are established between the compartment containing the nitrogen bank valves and the off-hull charging unit.

7. Check the submarine's planned maintenance records to verify that nitrogen gages meet the existing calibration requirements. All 4,500 lb/in^2 banks and 3,000 lb/in^2 banks should be charged to 4,750 lb/in^2 and 3,100 lb/in^2 respectively, maximum. They may be charged to a lower pressure depending upon the setting of the discharge pressure switch on the nitrogen charging unit, which shuts down the charging unit's liquid nitrogen pump.
8. Check portable nitrogen charging line pressure gage and pressure relief valve for proper calibration and setting, respectively, to prevent overpressurization of the submarine's nitrogen system. Relief valve pressure settings shall be 3150 psig plus or minus 50 psig and 5500 psig plus or minus 100 psig for systems of 3000 psig and 4500 psig normal operating pressures, respectively. These charging-line valves ensure that the maximum pressure in the submarine nitrogen system does not exceed hydrostatic test pressure in the event of malfunction of the pressure cutout or relief valve in the charging activity's equipment.
9. Ensure that all personnel are kept clear of topside nitrogen charging areas to avoid injury in the event of charging line rupture and the resultant whipping of the charging line.

550-7.22.5 PURGE AND PRESSURE TEST OF NITROGEN CHARGING LINE. When the charging line has been connected and all nitrogen charging preparations have been completed in accordance with paragraphs 550-7.22.2 through 550-7.22.4, proceed as follows:

1. Ensure that the nitrogen charging valve, check valve bypass, and bleed valves are closed. Instruct the charging unit operator to build charging line pressure slowly to 4,750 lb/in^2 or 3,150 lb/in^2 , as appropriate.
2. Leak test all threaded connections using leak detection compound, in accordance with MIL-L-25567.
3. After holding pressure for a sufficient length of time to ensure no leaks, purge the charging line through the ship's charging line bleed connection for about 5 minutes. During this time, provide maximum ventilation in the compartment into which the nitrogen is being bled and test the compartment atmosphere using a portable atmospheric oxygen analyzer.
4. Upon completion of purging, line up the nitrogen system for charging, except for the charging valve, which must remain closed.

550-7.22.6 CHARGING PROCEDURE. Under the supervision of the Officer in Charge, charge a submarine nitrogen system as follows:

1. Maintain sound-powered telephone communications between the charging petty officer in the compartment and the charging unit operator at all times. Close coordination between these two must be maintained throughout the charge.
2. Slowly open the charging valve to equalize pressure between the banks and the charging line.
3. Instruct charging unit operator to commence charging operation.

WARNING

Carryover of liquid nitrogen into the charging line and the submarine system is extremely hazardous and must be prevented.

4. During the entire time that the charging line is pressurized with nitrogen, use an oxygen analyzer in the vicin-

ity of the charging connection and in the missile compartment to determine if normal atmospheric conditions are being maintained. Also, frequently check threaded fittings topside for leaks.

5. If there are any indications of leaks, pump or vaporizer maloperation, icing of charging line, or failures of any nature, secure the nitrogen charge.
6. Monitor the nitrogen bank pressure at all times during the charging operation.

550-7.23 SECURING PROCEDURE

550-7.23.1 When the nitrogen banks are at the required pressure, secure the liquid nitrogen pump and vaporizer on the charging unit.

550-7.23.2 Secure the submarine nitrogen system as follows:

1. Check that all bank stop valves and the charging valve are shut.
2. Open the check valve bypass stop valve and vent the charging line to atmospheric pressure by using the bleed valve at the tender charging station or at the shore unit charging system vaporizer.
3. Disconnect the charging line, install caps on the charging line end fittings, place ends in polyethylene bags, bag the charging line fittings and remove the charging line from the ship. Cap the charging connection. Install union blinds at each end of the submarine's portable charging line; place ends in polyethylene bags and store line onboard.
4. Restore all shipboard conditions to normal and remove charging site restrictions.

550-7.23.3 Secure charging equipment as follows (not applicable where a commercial source is used):

1. Immediately upon securing pump, close tank pressure buildup and pump inlet valve.
2. Open the pump low-pressure and high-pressure bleed valves slightly to depressurize pump and to permit vaporization of any liquid nitrogen within the charging unit.
3. Slowly open the storage tank vent valve to relieve pressure. Leave the vent valve open after atmospheric pressure has been reached.
4. Follow instructions in the equipment technical manual for warming the pump and, if required, for purging the pump prior to securing the charging system.
5. Disconnect power leads, if applicable.

550-7.24 SUBMARINE NITROGEN SYSTEM OFFLOADING

550-7.24.1 GENERAL. A qualified officer shall be placed in charge of every nitrogen offloading operation, directly supervising compliance with the offloading procedure of either paragraph 550-7.24.2 or 550-7.24.3, as appropriate.

550-7.24.1.1 The Commanding Officer or Officer in Charge shall designate and formally certify trained personnel as authorized to conduct the nitrogen offloading process. For personnel training requirements, see paragraph

550-6.3. Each ship or shore activity involved shall prepare detailed procedures and checkoff sheets using the instructions given herein as a guide. All applicable safety precautions in paragraph 550-1.4.7 and elsewhere in this manual shall be observed during such operation.

550-7.24.1.2 The Officer in Charge shall ensure that offloading takes place only when the submarine is surfaced and the vented nitrogen can be bled downwind of any dockside facilities or submarine tender intakes.

550-7.24.1.3 If the offloading results from the need for extensive system or flask maintenance, the pressure shall be discharged to zero gage. If the offloading is for other reasons, a residual pressure of 100 lb/in^2 shall be retained to prevent the entrance of moisture or contaminants into the system.

550-7.24.2 OFFLOADING THROUGH THE NITROGEN CHARGING SYSTEMS PIPING. If nitrogen banks can be discharged through nitrogen system piping, offload nitrogen as follows:

1. Clean end fittings in accordance with MIL-STD-1330.
2. Connect the ship's portable charging line to the submarine charging connection. Connect offloading line to the submarine's portable charging line. The offloading line may be the charging line or another line used primarily for this operation.
3. Rig offloading line to discharge downwind of any ventilation intakes. Secure the line to prevent possibility of whipping.
4. Open nitrogen system charging and check valve bypass valves.
5. Slowly open the first bank's cutout valve; slowly discharge bank to a pressure gage reading of 100 lb/in^2 or zero gage pressure, as required.
6. Repeat step 5 above until all banks are bled down to 100 lb/in^2 or zero gage pressure, as required.
7. During nitrogen offloading, use an oxygen analyzer in the vicinity of the charging connection and in the missile compartment of FBM submarines to determine if normal atmospheric conditions are being maintained.
8. When all banks have been bled down to 100 lb/in^2 or zero gage pressure, secure the nitrogen system charging and check valve bypass valves.
9. Disconnect the offloading line, clean and bag end fittings, and remove the line from the ship. Clean and cap the charging connection. Install union blinds at each end of the ship's portable charging line; seal ends in polyethylene bags and store line onboard.

550-7.24.3 ALTERNATE OFFLOADING PROCEDURES (SSBN 623 and LATER SSN SUBMARINES). Certain nitrogen banks (bank nos. 2 and 3 or 3 and 4 on SSBN 623 through SSBN 636 and bank nos. 1 and 2 on SSBN 640 through SSBN 659) cannot be offloaded through the nitrogen charging system piping (see paragraph 550-7.24.2), because the installed check valve has no bypass. In such cases, offload nitrogen using one of the two procedures specified in paragraphs 550-7.24.1.3 through 550-7.24.3.1. The empty tube procedure is preferred. The residual pressure shall be 100 lb/in^2 or zero gage pressure, as required (see paragraph 550-7.24.1.3).

550-7.24.3.1 Offloading Through an Empty Missile Tube. If an empty missile tube is available, offload the nitrogen through the empty tube.

550-7.24.3.1.1 Prepare for offloading as follows:

1. Ensure that the missile tube is empty and that no inner tube diaphragm is in place.
2. Line up valves and observe safety precautions as for missile tube pressurization with nitrogen except as modified herein.

550-7.24.3.1.2 Offload nitrogen through the empty missile tube as follows:

1. Open the muzzle hatch and ensure that the missile tube access doors are shut.
2. Manually operate the breather valve to discharge nitrogen slowly to the missile tube. The nitrogen banks will be offloaded to the atmosphere through the missile gas system by way of the missile tube.

550-7.24.3.1.3 During the offloading operation, heed the following precautions:

a. Discharge nitrogen at a slow rate in order to minimize cooling of launcher system components.
b. Immediately after offloading nitrogen through the missile tube, thoroughly purge the missile tube with air. The purge is completed when the missile tube has been tested to contain 20-22 percent oxygen.

550-7.24.3.2 Offloading Through the Ballast Tank. If an empty missile tube is not available, offload the nitrogen by cross-connecting the nitrogen system with the ship's high pressure air system. (For SSBN 640 class submarines, this requires installing the portable jumper pipe between the two systems in the missile compartment.) After the systems are lined up, offload the nitrogen through the ballast tanks.

550-7.24.3.2.1 Prepare for offloading as follows:

1. Ensure that all normally closed, high-pressure (HP) air, main ballast tank (MBT) blow, and nitrogen system valves are secured.
2. Shut nitrogen bank valves.
3. Tag all normally open valves that are closed for the offloading procedure to ensure they are opened after offloading of nitrogen.

550-7.24.3.2.2 Offload the nitrogen through the ballast tanks as follows:

1. Secure appropriate isolation valves to isolate all portions of the nitrogen system not required for the offloading flow path.
2. On SSBN 640 class submarines, install the portable jumper pipe to cross-connect the air and nitrogen systems in the missile compartment.
3. At the ballast control panel (BCP), isolate the air banks from the 4,500 lb/in^2 g header by moving control switches for air bank isolation valves to **SHUT** .
4. Secure all appropriate isolation valves to isolate all sections of the HP air and MBT blow piping not required for the flow path to offload nitrogen.
5. Open isolation valve(s) for nitrogen bank(s) being offloaded.
6. Open hull valve(s) for MBT(s) selected for offloading nitrogen; close hull valves for the remaining MBT(s).

7. Slowly open the nitrogen system valve(s) to establish required flow path from the nitrogen bank(s) to selected ballast tank(s).

8. At the BCP, move the appropriate group blow switch to open and discharge nitrogen into selected ballast tank(s).

9. When pressure in the nitrogen bank(s) has been reduced to the desired pressure, restore nitrogen system valve(s) to normal position. On SSBN 640 class submarines, remove the portable jumper pipe used to cross-connect the air and nitrogen systems.

550-7.24.3.2.3 During offloading operation, heed the following precautions:

a. Open the required high-pressure air valves and purge the nitrogen from all high-pressure air piping to ballast tanks. The purge is completed when the selected main ballast tank has been tested to contain 20-22 percent oxygen.

b. Restore the high-pressure air system valve(s) to normal position.

c. Purge the emergency breathing air system to ensure that it is free of excess nitrogen.

550-7.25 CLEANING AND TESTING OF SHIPBOARD OXYGEN, NITROGEN, AND HYDROGEN GAS PIPING SYSTEMS

550-7.25.1 Shipboard oxygen, oil-free nitrogen, helium, and helium-oxygen systems shall be cleaned in accordance with procedures specified in MIL-STD-1330, **Cleaning and Testing of Shipboard Oxygen, Nitrogen and Hydrogen Gas Piping Systems** .

550-7.25.2 Work or maintenance evolutions accomplished on oxygen, nitrogen, and helium systems should be in accordance with MIL-STD-1330.

550-7.26 HIGH-PRESSURE GAS FLASKS

550-7.26.1 Storage flasks for oxygen, nitrogen, helium, and other gases are fabricated in accordance with MIL-F-22606 for ships built after 1963. For specifications, physical characteristics, and tolerances of these and the flasks installed in earlier ships, see Table 550-7-2 and **NSTM Chapter 551, Compressed Air Plants** . The interiors of submarine missile gas nitrogen flasks that may alternately be used for air storage are painted in accordance with the requirements for Service A flasks of MIL-F-22606.

550-7.26.2 Inspect the external surface of installed nitrogen and other gas flasks except oxygen flasks at periods not to exceed 6 years. Remove all rust, dirt, and loose paint and recoat the exterior surface with wash primer, formula 117, in accordance with MIL-P-15328. Follow with an application of vinyl zinc chromate formula 120 in accordance with MIL-P-15930. As an alternative, follow with the application of a paint system that is the same as that used in the vicinity of the flask installation. At each dry docking, visually inspect submarine oxygen and nitrogen flasks located in the ballast tanks. Look for breaks in the paint coating, loose foundations, and other defects. Correct all defects found.

550-7.27 SUBMARINE OXYGEN AND NITROGEN SYSTEM INSPECTION REQUIREMENTS FOR BANK FLASKS

550-7.27.1 HIGH PRESSURE GAS FLASKS. Permanently installed storage flasks for oxygen, nitrogen, helium and heliox mixtures are fabricated in accordance with MIL-H-22606 for ships built after 1963. Flasks are designated as either Service A (Compressed Air), or Service B (Oxygen and Oil-free Nitrogen, including Helium and Heliox mixtures). Older ships will have flasks in accordance with MIL-C-15111 (surface ships) and MIL-C-2809 (submarine). These flasks are designated Service B and as such are not painted on the interior like air flasks which are designated Service A. Whether the interior paint or unpainted is the only difference between the two services, all other characteristics such as cubic capacity, weight, wall thickness and pressure rating are identical. Physical characteristics for various high pressure gas flasks are as shown in Table 550-7-2.

550-7.27.1.1 General. Inspection and recertification of all flasks, both Service A and Service B, shall be in accordance with the requirements of **NSTM Chapter 551** (Section 1), except that the interior of Service B flasks shall not be painted but shall be phosphated only. Additional inspection and recertification requirements for Service B flasks are contained in the following paragraphs.

550-7.27.1.1.1 The recertification, inspection, and cleaning of oxygen, helium, and heliox mixture flasks supporting Diving and Deep Submergence Systems certified per NAVSEA SS800-AG-MAN-010/ P-9292 **(Systems Certification Procedures and Criteria Manual for Deep Submergence Systems**) and NAVSEA SS521-AA-MAN-010 (**U.S Navy Diving and Manned Hyperbaric Systems Safety Certification Manual**), shall be specified by NAVSEA.

550-7.27.1.1.2 The separator flask for oxygen service is fabricated in accordance with MIL-F-24032. This flask is made of K-monel and its primary function is to remove possible potassium hydroxide (KOH) carryover from the oxygen generators. This flask shall not be painted either internally or externally.

Table 550-7-2. STORAGE SPECIFICATIONS FOR HIGH-PRESSURE GAS FLASKS

Specification	Working Pressure (Pounds Per Square Inch)	Diameter (Inches)	Minimum Allowable Wall Thickness (Inches)
51F5 of MIL-C-15111	3,000	5-1/4 ID 16 ID	0.21 (Obsolete) 0.64
MIL-F-22606	3,000 5,000	18 OD 6-5/8 OD	0.50 0.40
MIL-F-24032	3,000	6-5/8 OD	0.375
NOTE: The 5-1/4-inch ID and 6-5/8-inch OD flasks are used as separator flasks to remove the potassium hydroxide (KOH) carryover. The other flasks are installed singularly or in banks for storage of nitrogen, oxygen, and other gases. The flasks are unpainted on the inside because the gases stored are dry and little if any deterioration takes place.			

550-7.27.1.2 KOH Inspection. KOH deposits from the oxygen generator will not attack the materials found in the submarine oxygen system including the flask, except at temperatures in excess of 149°C (300°F). However, KOH deposits in powder or scale form can foul system valves and contaminate the oxygen. Accordingly, inspect the separator flask and downstream system for evidence of KOH contamination at every overhaul. Submarines which do not have an after cooler and moisture separator, such as SSBN 627 Class, shall have an inspection at every regularly scheduled drydocking. If KOH is detected, clean the affected portions in accordance with MIL-STD-1330. If inspection indicates that KOH carryover may have extended to the bank flasks, select a sample flask

to be opened for visual inspection to determine the extent of KOH contamination. The sample flask shall be the nearest to the header. If contamination is found, the next flask in the series shall be examined until no contamination is found. Clean KOH contaminated oxygen flasks in accordance with MIL-STD-1330.

550-7.27.1.3 Recertification Periodicity. Service B flasks shall be recertified in accordance with the following periodicity requirements:

a. Surface ships. Service B flasks shall be recertified at every other recertification of Service A flask but not to exceed 14 years.

b. Submarines. Service B flasks shall be recertified on the same periodicity permitted for Service A flasks as indicated on Table 551-1A of **NSTM Chapter 551** .

550-7.27.1.3.1 After recertification, all oxygen and oxygen clean nitrogen flasks shall be internally inspected and cleaned in accordance with MIL-STD-1330. Oxygen clean nitrogen flasks are defined as those nitrogen flasks which store nitrogen used for purging an oxygen system or the oxygen generator, pressuring mixing the demineralized water tank, or filling portable nitrogen bottles. In addition, oxygen clean nitrogen flasks are those that are charged with nitrogen directly from the oxygen-nitrogen plants on CV/CVN and AS Class ships as described in paragraphs 550-7.7.3 and 550-7.8.3.1.

550-7.27.1.3.2 For each submarine missile gas nitrogen bank, select one sample flask to be opened for an interior inspection in accordance with MIL-STD-1330. If the results of the interior inspection are satisfactory, assume all remaining flasks in the bank are also satisfactory. If the results of the interior inspection are not satisfactory, open and inspect all remaining flasks in the associated bank. Post inspection cleaning of missile gas nitrogen flasks shall be accomplished in accordance with NAVSEA 0900-LP-092-0010, **Standard Procedures for Cleaning High Pressure Air Flasks Onboard Nuclear Attack Submarines** .

SECTION 8.

SHIPBOARD OXYGEN-NITROGEN PLANT PRODUCT QUALITY REQUIREMENTS

550-8.1 SCOPE

550-8.1.1 This section describes the requirements for surface ship oxygen-nitrogen plant product testing and provides guidance about product quality. Test procedures are described. The sampling, testing, and test frequencies described here are the basic requirements for characterizing the oxygen-nitrogen, and for indicating potential contamination which warrants troubleshooting and corrective action. These basic requirements are consistent with Military, Specification MIL-O-27210 and the Aviators' Breathing Oxygen Surveillance Program for oxygen quality. These requirements are consistent with BB-N-411 Federal Specification for nitrogen quality.

550-8.2 TESTING REQUIREMENTS

550-8.2.1 The oxygen and nitrogen product of shipboard oxygen-nitrogen (O_2 N_2) plants shall be tested regularly for purity and for contaminant content. Each shipboard O_2 N_2 plant work center shall have and maintain serviceable all the necessary apparatus for measuring oxygen and nitrogen bulk purity percentage, for testing oxygen and nitrogen for odors, for testing liquid oxygen for acetylene, and for obtaining liquid oxygen samples to be analyzed for trace contaminant content. The test results shall be recorded on the O_2 N_2 Plant operating log.

Tests of samples are to be done at intervals as explained below. The periodicities stated here do not preclude more frequent testing which will depend on local conditions and whether product contamination is suspected.

550-8.3 ANALYSES FOR OXYGEN AND NITROGEN PURITY PERCENTAGE

550-8.3.1 GENERAL. Oxygen purity is analyzed during oxygen production and nitrogen is analyzed during nitrogen production utilizing either an electronic, bulk purity analyzer or an Orsat chemical test. The gaseous sample for analysis and testing is obtained from the O_2 N_2 producer via installed tubing which connects the producer's process sample tap to the electronic analyzer's and the Orsat test set's sample inlet connections. The purity percentage of the oxygen-nitrogen shall be as specified in the applicable O_2 N_2 producer technical manual. If the specified minimum purity is not indicated, then corrective action shall be taken.

550-8.3.1.1 Prior to beginning oxygen-nitrogen transfer to storage, the percentage purity shall be analyzed and tested.

550-8.3.1.2 During production, if equipped with an electronic analyzer, the purity is to be monitored continually and the purity value recorded hourly. An Orsat chemical test must be done at least once every eight hours for comparison with the electronic analyzer. If an electronic analyzer is not installed or is not functioning properly, then hourly Orsat tests shall be done.

550-8.3.2 TEST FOR ACETYLENE IN OXYGEN. Oxygen is tested for acetylene content during oxygen-nitrogen production and while there is liquid stored in the oxygen tank. The liquid sample for testing is obtained from the O_2 N_2 producer via a designated liquid oxygen sample outlet or a drain outlet from the oxygen column sump, reboiler, or oxygen side of the nitrogen condenser. The liquid sample is obtained from the oxygen storage tank via a suitable liquid service outlet or the empty trycock. The acetylene content shall not exceed 2 p/m by weight. If excessive acetylene is detected, then corrective action shall be taken.

550-8.3.2.1 During O_2 N_2 producer operation, test for acetylene within four hours after starting oxygen-nitrogen production and then at least once every 24 hours. During oxygen production, test product oxygen; during nitrogen production, test oxygen tank or crude oxygen in the oxygen column sump, reboiler, or oxygen side of the nitrogen condenser.

550-8.3.2.2 While a tank contains liquid oxygen, test for acetylene at least once every seven days.

550-8.3.3 TEST FOR OXYGEN AND NITROGEN ODOR. Oxygen and nitrogen are tested for odor during oxygen-nitrogen production and while there is liquid stored in the oxygen-nitrogen tank. The liquid sample for testing is obtained from the storage tank via a suitable, liquid service outlet or the empty trycock. The oxygen-nitrogen should be odorless. If odor is detected, then corrective action shall be taken.

550-8.3.3.1 During production, test for oxygen and nitrogen odor four to eight hours after the start of product transfer to the tank.

NOTE

If the producer has a liquid oxygen-nitrogen sample valve outlet, the liquid sample may be obtained therefrom, rather than from the tank.

550-8.3.3.2 Test for odor after completing the addition to the tank, or if in continuous production, test at least once every 24 hours.

550-8.3.3.3 While tank contains liquid, test for odor at least once every seven days.

550-8.4 ANALYSIS FOR TRACE CONTAMINANTS IN OXYGEN

550-8.4.1 Oxygen is sampled and sent to a designated test site for trace contaminant analysis during oxygen production and while there is liquid stored in the oxygen tank. The liquid sample for testing is obtained from the product oxygen receiver, the storage tank, via a suitable liquid service outlet or the empty trycock. O_2 N_2 plant work centers in aviation support ships (e.g., CV/CVN) accomplish the sampling for trace contaminant analysis pursuant to the Aviators' Breathing Oxygen (ABO) Surveillance Program and the oxygen is analyzed for compliance with the constituent limits of MIL-O-27210 in accordance with the directions and restrictions of technical manual NAVAIR A-6-332A0-GYD-000. Trace contaminant values for ABO are outlined by Table 550-8-1 for informational purposes. O_2 N_2 plant work centers in non-aviation support ships (e.g., AS) accomplish the sampling for analysis to determine if the oxygen is acceptable for uses for which MIL-0-27210 is specified - e.g., divers' breathing gas and ABO gas cylinder charging. Regardless of the trace contaminant analysis, for charging submarines there is no restriction on the use of shipboard produced oxygen that has acceptable purity percentage and is odorless. If the trace analysis contaminant results do not meet usage requirements, then corrective action shall be taken.

550-8.4.1.1 Obtain a sample for analysis four to eight hours after the start of oxygen product transfer to the tank, if the tank already contains liquids oxygen.

550-8.4.1.2 Obtain a sample for analysis after 200 to 250 gallons have accumulated, if the tank was empty at the start of production.

NOTE

If producer has a liquid oxygen sample valve outlet, the liquid sample may be obtained therefrom rather than from the tank four to eight hours after the start of product transfer to the tank. If aviation support ships regularly obtain the sample from the producer, then periodic samples from the oxygen tank must be analyzed in accordance with ABO Surveillance Program requirements.

550-8.5 SAMPLING AND TESTING PROCEDURES

WARNING

Forces afloat comply with Navy Safety Precautions for Forces Afloat, OPNAVINST 5100 series. Only MM-4283-NEC qualified personnel familiar with oxygen-nitrogen safety precautions are to perform O_2 N_2 Sampling and Testing. See Section 6. Wear faceshield, protective gloves, ″LOX″ shoes and coveralls when doing liquid oxygen-nitrogen sampling and testing.

Table 550-8-1. ABO CONTAMINATION LIMITS NOTE 1
MAXIMUM CONCENTRATION (PPM BY VOLUME) ALSO REFER TO
NAVAIR A6-332AO-GYD-000

PURITY - 99.5% VOLUME ODOR - NO ODOR				
CONSTITUENT	**TYPE II (LIQUID OXYGEN)**		**TYPE I (GASEOUS OXYGEN)**	
	Procurement/ Generated Limits	**Use Limits**	**Procurement/ Limits**	**Use**
Carbon Dioxide Co_2	5	10	10	20
Methane CH_4 NOTE 2	25	50	50	100
Acetylene $C_2 H_4$	0.2	0.4	0.4	0.8
Ethylene $C_2 H_4$	0.2	0.4	0.4	0.8
Higher Hydro Carbons Ethane Equivalent, C_{2+}	3	6	6	10
Nitrous Oxide $N_2 O$	2	4	4	6
Halogenated Compounds				
Total Refrigerants	1	2	2	4
Total Solvents	0.1	0.2	0.2	0.4
Moisture $H_2 O$	7	14	7	14
(Dewpoint F) at 14.7 psia	(-82)	(-58)	(-82)	(-58)
Other	0.1	0.2	0.2	0.4

NOTES:

1. Procurement limits are for liquid and gas as specified by MIL-0-27210. Use limits are for liquid when sampled out of the liquid storage tank and for gas when sampled out of gas cylinders.
2. For carrier produced liquid oxygen, the Use Limit for Methane when sampled at the storage tank is 75 PPM.

550-8.5.1 PURITY TEST. An Orsat test procedure for oxygen-nitrogen is described below. Also, detailed Orsat test procedures and the test apparatus are described by the technical manual for each oxygen-nitrogen producer. The Orsat test apparatus, replenishment supplies and parts are provided by either AEL 2-870004140 or 2-870004145, as identified by the Consolidated Shipboard Allowance List (COSAL) for each ship. Operating procedures for the Servomex model 540 electronic, oxygen-nitrogen purity analyzer are in technical manual NAVSEA S9553-AN-MMC-010. Repair parts for the analyzer are provided by APL 469990121. Electronic analyzer models other than the servomex 540 are covered by technical manuals and APLs for the oxygen-nitrogen producers on which those analyzers are mounted.

550-8.6 TEST PROCEDURES

550-8.6.1 ORSAT TESTS

550-8.6.1.1 Prepare oxygen test solution.

1. Mix one volume of commercial 28% ammonium hydroxide (NH_4 OH) with two volumes of distilled water.

WARNING

Wear safety goggles or a face shield while using test set. Do not inhale ammonia fumes; ammonia solution is caustic, and care should be taken to prevent contact with the skin. If ammonia splashes on skin, wash off immediately with water and apply a solution of boric acid dissolved in water. If ammonia solution comes in contact with the eyes, immediately flush with water and then apply diluted boric acid solution.

2. Saturate mixture by adding ammonium chloride (NH_4 Cl). Chemical reaction will cause the solution to become cold; allow solution to warm and continue adding ammonium chloride. The solution will be saturated when solid crystals of ammonium chloride remain on bottom of container after it has been thoroughly mixed and allowed to warm.
3. Mix several gallons of test solution at a time, while plant is operating. Store in stoppered glass containers.

550-8.6.1.2 Add Reagents.

1. Lift glass reacting tube out of reservoir, remove stopper, and fill tube to top with copper wire. Replace stopper and return reacting tube to its position in reservoir.
2. Pour fresh test solution into reservoir until it is about three-fourths full.
3. Remove leveling bulb from its holder. Hold it below the level of the burette and pour in test solution until it is half full. Return bulb to its holder.

550-8.6.1.3 Prepare oxygen test set for operation.

1. Inspect test set and make certain that all connections are tight.

WARNING

When connecting the source of gas to be sampled, be certain that a low-pressure regulator is used in the line to prevent application of excessive pressure to glass vessels of the test set.

2. Check stopcock to see that it turns freely. If it does not, it should be removed, cleaned, and lubricated.

WARNING

Never use hydrocarbon-based lubricants where they will come into contact with oxygen. An explosion can result. Use only fluorocarbon wax such as Air Products No. 2-370-39-0001 as a stopcock lubricant.

3. Be sure that glass reacting tube is filled to the top with copper wire.
4. Observe color of test solution. If a greenish-brown discoloration is noted in glassware, drain one half of solution and replace with an equal quantity of fresh solution. Place this fresh solution in reservoir.
5. Check to see that solution reservoir and leveling bulb are at least half full of satisfactory test solution.
6. Turn burette stopcock so that burette is connected with reacting tube.
7. Lower leveling bulb until solution passes from reacting tube through interconnecting rubber tubing and into burette. Pinch rubber tubing a few times to liberate any gas bubbles.
8. When reacting tube appears full of solution and free of gas bubbles, and solution completely fills glass and rubber sections between reacting tube and burette chamber, turn burette stopcock handle to closed (horizontal) position.
9. Open burette stopcock one-fourth turn to connect burette to atmosphere through small glass connection.
10. Slowly raise leveling bulb, causing solution to rise in burette. When solution has completely filled burette and is just about to flow out of glass connection to atmosphere, close stopcock. The inside of burette must be absolutely free of gas bubbles.

550-8.6.1.4 Test oxygen sample.

1. Crack oxygen purity test valve. Purge test line for a minute or two to ensure that a representative sample of oxygen is taken for analysis.
2. Connect rubber tube on the end of this test line to glass connection on burette of test set.
3. Open burette stopcock so that oxygen gas may pass into burette, forcing liquid up in leveling bulb. Fill burette with oxygen to slightly below zero mark at its lower end. Do not open oxygen test valve too wide, or oxygen will enter the burette too rapidly and will be difficult to stop near zero mark. Better control can usually be obtained by pinching sample line rubber tube connected to burette inlet.
4. When burette is filled to slightly below its zero mark, pinch rubber tube connecting the burette to leveling bulb, and remove rubber tube connecting burette to the sample line.
5. Since level in burette is lower than zero mark, more than 100 milliliters of gas are in burette. Release rubber tube slightly until zero mark is reached, then close stopcock.
6. Turn burette stopcock so that burette is connected to reacting tube.
7. Pass gas sample back and forth three or four times between burette and tube by alternately raising and lowering leveling bulb.
8. The volume of gas sample diminishes greatly after first passage into reacting tube. Oxygen in sample reacts with copper to form an oxide, which is then dissolved by test solution. After first passage of sample, this decrease in sample volume becomes progressively smaller until all oxygen has reacted with copper. All unreactive impurities remain undissolved. The principle impurities in pure oxygen are argon and nitrogen.

550-8.6.1.5 Read oxygen purity.

1. With undissolved gas in reacting tube, lower leveling bulb for final transfer to burette. Pinch interconnecting tubing several times so that no gas bubbles are trapped in tubing.
2. When all of undissolved gas has been passed into burette, close stopcock.

3. Equalize levels of solution in burette and leveling bulb by raising or lowering leveling bulb. Read solution level on burette scale. This reading is equal to purity percentage of original oxygen sample. Repeat steps until two identical oxygen purity readings are obtained.

550-8.6.1.6 Prepare nitrogen test solution.

1. Dissolve 450 grams (1 lb) of sodium hydroxide (NaOH), or 570 grams (1 1/4 lbs.) of potassium hydroxide (KOH) in about 500 cc (1 pt) of distilled water. Add enough additional water to make 1 liter (about 1 qt) of solution. Solution will warm. Let solution cool. Mix solution in glass jar to avoid contaminating solution with metallic scale or other foreign matter. Use a dark glass jar. Dark glass minimizes solution deterioration due to exposure to direct light.

WARNING

Wear safety goggles or a face shield while using test set. The potassium hydroxide solution is caustic and care should be taken to prevent contact with the skin. If caustic splashes on skin, wash off immediately with water and apply a solution of boric acid dissolved in water. If caustic solution comes in contact with the eyes, immediately flush with water and then apply diluted boric acid solution.

2. Dissolve 60 grams (about 1/8) of pyrogallic acid crystals (C6H3 (OH)3), commonly called pyrogallol, in the caustic solution just before test solution is required for use. Test solution must be kept tightly covered to prevent deterioration due to absorption of oxygen from the atmosphere.
3. Fill reacting tube and reservoir half full of fresh test solution. Fill leveling bulb with distilled water.

550-8.6.1.7 Prepare nitrogen test set for operation.

1. Mark the reacting tube approximately 1/2 inch above the neck. Turn the burette stopcock so that the burette is connected to the reacting tube.
2. Lower leveling bulb until liquid in reacting tube comes up to the mark on neck of the reacting tube. Pinch rubber tubing several times to liberate gas bubbles.
3. When reacting tube appears full of liquid and free from gas bubbles, and liquid comes up to the mark on the neck of the reacting tube, turn burette stopcock handle to a closed (horizontal) position.

NOTE

Never allow pyrogallate solution to enter the burette.

4. Open burette stopcock one-fourth turn to connect burette to atmosphere through the small glass connection.
5. Slowly raise leveling bulb, causing water to rise in burette. When water has completely filled burette and is about to flow out of glass connection, close stopcock. The inside of the burette must be absolutely free from gas bubbles.

550-8.6.1.8 Test nitrogen sample.

1. Crack nitrogen purity test valve for a few minutes so that a representative sample of nitrogen is taken for analysis.
2. Connect rubber tube on end of the nitrogen test line to glass connection on burette of test set.

WARNING

When connecting the source of gas to be sampled, be certain that a low-pressure regulator is used in the line to prevent application of excessive pressure to glass vessels of the test set.

3. Open burette stopcock so that nitrogen gas sample may pass into burette. Fill burette with nitrogen to slightly below zero mark at its lower end. Do not open nitrogen test valve too wide or nitrogen will enter burette too rapidly and will be difficult to stop near zero mark. Better control can usually be obtained by pinching sample line rubber tube connected to burette inlet.
4. When burette is filled to slightly below its zero mark, pinch rubber tube connecting burette to leveling bulb, and remove rubber tube connecting burette to sample line.

NOTE

When first entering burette, nitrogen sample will be colder than room temperature and will expand as it warms. For maximum accuracy, allow sample to warm to room temperature before adjusting level to zero mark.

5. Since level in burette is lower than zero mark, more than 100 milliliters of gas are in burette. Release rubber tube slightly until zero is reached, then close stopcock.
6. Raise leveling bubble above the stopcock level and turn stopcock so burette is connected to reacting tube. The gas sample will be forced out of burette and into reacting tube.

NOTE

Never allow water in burette to pass into reacting tube. Pinch rubber tube connecting leveling bulb to burette to obtain exact control necessary.

7. Allow water in burette to rise to stopcock and close stopcock. Leave gas sample in reacting tube until glass tube bundle looks clear, indicating complete absorption.
8. Turn stopcock to reconnect reacting tube with burette. Lower leveling bulb and allow pyrogallate solution to rise in reacting tube.

NOTE

Never allow pyrogallate solution to enter burette.

9. Transfer sample back into reacting tube by repeating steps 5., 6. , and 7. This allows gas that was trapped in rubber tubing at top of reacting tube during first absorption to come into contact with pyrogallate solution. Continue passing gas back and forth between burette and reacting tube until no further reduction in sample volume takes place. Three or four passages are usually sufficient.

550-8.6.1.9 Read nitrogen purity.

1. Turn stopcock to reconnect reacting tube with burette. Lower leveling bulb and allow pyrogallate solution to rise to mark on the neck of the reacting tube, then close stopcock.
2. Equalize liquid levels in burette and the leveling bulb by adjusting height of leveling bulb, and note reading on burette scale at liquid level. This reading is equal to the percentage of purity of the original nitrogen sample.

NOTE

The gas sample may be warm due to chemical reaction. Allow it to cool to room temperature before obtaining final reading.

550-8.6.2 ACETYLENE TEST PROCEDURE. A test for acetylene in liquid oxygen is described here. This test has been standard for many years. Required apparatus and materials are provided by either AEL 2-870004080 or 2-870004143, as identified by the COSAL for each ship. Some oxygen-nitrogen producer technical manuals include acetylene test details. Another acetylene test, based on the same chemical reaction principles, but with a different procedure and different apparatus (including an electronic colorimeter instead of visual comparison color standards) is being introduced to Fleet use. This newer test method is described by Technical Manual NAVSEA ST990- A8-MMI-010, and APL 469990156S. Each O_2 N_2 plant work center should use whichever acetylene test apparatus it has available.

NOTE

Test tubes shall be kept clean and dry to reduce possibility of contamination.

550-8.6.2.1 Prepare acetylene test solution.

1. Add 1 gram of soluble starch to 10 milliliters of distilled water and stir to form a thin paste. Pour paste into 200 milliliters of boiling distilled water and stir. Allow to cool.
2. Dissolve 5 grams of copper sulfate ($CuS04.5H_2$ O) in about 500 milliliters of distilled water in a 1 liter volumetric flask.
3. Add 50 milliliters of concentrated ammonium hydroxide (specific gravity at 60/60) F = 0.900: assay 28.4% NH_3) to copper sulfate solution.
4. Add starch solution prepared in step 1. to copper ammonia solution and dilute to 1 liter mark with distilled water. Store in test solution addition bottle.

NOTE

Acetylene test solution has a deep blue coloration.

550-8.6.2.2 Prepare hydroxylamine hydrochloride solution by dissolving 36.0 grams of hydroxylamine hydrochloride in 100 milliliters of distilled water and store in 4-ounce polyethylene dropping bottle.

550-8.6.2.3 Purge sample line before obtaining a liquid oxygen sample. Pre-cool 1-quart Dewar flask by filling with liquid from sample line. Allow to stand about 1 minute. Discard contents of Dewar and refill from sample line.

550-8.6.2.4 Perform test.

NOTE

Use a clean, dry 6-inch Pyrex test tube calibrated at the 3 milliliter and 20 milliliter levels to perform this test.

1. Add 1/4 milliliter (0.3 grams) of silica gel powder to test tube and slowly immerse test tube in wide-mouthed Dewar which has been previously filled with liquid nitrogen. Using test tube clamp as a ″rest″ on edge of Dewar, support test tube in an upright position so that level of liquid nitrogen is at, or slightly above, 20 milliliter mark. Pour liquid oxygen sample from sample collection Dewar into subcooled test tube to 20 milliliter mark.
2. Slowly immerse glass stirring rod in liquid nitrogen until rod is cooled. Remove stirring rod and immerse in liquid oxygen sample; stir for 1-1/2 to 2 minutes. In stirring, attempt to bring all liquid in contact with gel.
3. When stirring is complete, remove stirring rod from tube and allow gel to settle to bottom (approximately 5 seconds). Remove sample tube from liquid nitrogen bath and pour out (decant) all liquid oxygen; exercise care to keep gel in bottom of tube. As quickly as possible, add acetylene test solution from test solution addition bottle to 3 milliliter mark.
4. When solution has warmed to ambient temperature, add exactly 12 drops of hydroxylamine hydrochloride solution and allow test tube to stand for 15 minutes.
5. Observe test solution. Appearance of any pink or red color indicates presence of acetylene. Compare any color developed with standards to determine acetylene content.

550-8.6.3 ODOR TEST PROCEDURES. The test for liquid oxygen and nitrogen odor is described here. Required apparatus and materials are covered by AEL 2-870004144. NAVAIR A6-332AO-GYD-000 manual and some oxygen-nitrogen producer technical manuals include odor test details.

NOTE

Accomplish test in an area free from air currents and airborne odors.

550-8.6.3.1 Purge sample line and obtain liquid oxygen or nitrogen sample in a Dewar flask (the acetylene test Dewar flask maybe used).

550-8.6.3.2 Place clean, dry, filter paper in the bottom of a 400 ml beaker and pour 200 milliliters of liquid sample into beaker.

550-8.6.3.3 Partially cover beaker with a watchglass; allow liquid to evaporate and the beaker to warm to room temperature.

550-8.6.3.4 When liquid has completely evaporated, remove the watchglass from the beaker and smell the contents at frequent intervals until accumulated frost on the outside of the beaker has melted. Odor will be most prevalent when the beaker has warmed to nearly room temperature.

550-8.6.4 TRACE CONTAMINANTS TEST. The procedure to obtain and forward a liquid oxygen sample for infrared spectrophotometer analysis is described here. The analysis shall be performed and the results determined by qualified personnel of a designated test site in accordance with NAVAIR A6-332A0-GYD-000.

Tools and Materials.

- Gloves, welders, gunn cut, cattlehide
- Wrench, adjustable, 15″ nonspark and nonmag, 1.698″ jaw open (2)
- G-276 Cryogenic Sampler, or Cosmodyne CS 4.4/CS 100 Cryogenic Sampler, or CV International FCS 2001 Sampler (samplers to be coordinated with the designated test site)
- Faceshield, industrial tilting, Size 4 Apron, toxicological agents protective
- Coveralls, toxicological agents protective
- Sample Description Form
- Drip Pan, aluminum
- Separator-Oxygen, Liquid Gas, NAS Alameda Dwg 412384 (for G276 sampler only)

Procedure to obtain sample:

NOTE

Sample must be forwarded to an approved ABO testing facility. That facility can be aboard ship or land-based.

NOTE

Use paragraph 8.6.4.1 for the G-276 sampler, paragraph 8.6.4.2 for the Cosmodyne CS 4.4/CS 100 sampler, and paragraph 8.6.4.3 for CV International FCS 2001 sampler.

550-8.6.4.1 For ships having a G-276 Sampler.

1. Inspect sampler for cleanliness and safety.
2. Bleed purge gas from sampler by slowly opening sample valve.
3. Connect a sample hose from sample source to liquid gas separator.
4. Remove sampler valve assembly from sampler. Place sampler in sampler stand.
5. Direct outlet of liquid gas separator toward drip pan.
6. Open liquid sample line valve to purge and cool down the hose and separator.
7. Close liquid sample line valve.

NOTE

Exercise care that frost that has formed on the outside of the separator does not fall into the sampler.

8. Place outlet of liquid gas separator directly over sampler inlet.
9. Open liquid sample line valve and pass sufficient liquid through separator to fill sampler (splashing liquid droplets are seen at sampler inlet).
10. Close liquid sample line valve.
11. Remove separator from sampler and reinstall sampler valve assembly.
12. Invert the sampler and submerge in water. Sample will vaporize and build pressure in sampler.
13. Inspect sampler for leakage and correct any that is found.
14. Forward sample and accompanying paperwork to the nearest approved testing facility.

550-8.6.4.2 For ships having a CS 4.4/CS 100 sampler:

1. Inspect sampler for cleanliness and safety.
2. Remove top of sampler case and remove protective caps from sampler inlet and outlet ports:
3. Connect a fill hose to sample source.
4. Connect remaining end of fill hose to sampler inlet port.
5. Connect an additional hose to outlet port of sampler and direct that hose toward a drip pan.

WARNING

Ensure that sample inlet valve at top of sampler is closed.

6. Open liquid line valve to begin cooling sample vessel.
7. When a steady stream of liquid has been emitted from sampler outlet port for 2 minutes, open sample inlet valve.
8. Allow sampler to fill for 60 seconds then close inlet valve.
9. Close liquid line valve at sample source.
10. When liquid ceases to flow from outlet line, disconnect line from sampler.
11. Disconnect fill hose from sample source and from sampler.
12. Replace protective caps on inlet and outlet ports.
13. Replace sample case top.
14. Invert sample case and keep it inverted for at least 5 minutes.
15. Forward sample and accompanying paperwork to nearest approved test facility.

550-8.6.4.3 For ships having a FCS 2001 sampler (also refer to technical manual NAVAIR AG-1155L-OMP-000):

1. Inspect sampler for cleanliness and safety.

2. Remove top of sampler case and protective caps for the charging manifold assembly (CMA) and cylinder assembly (CA) interconnecting ports.
3. Ensure that sealing ring is in place on the attachment port of CMA.

CAUTION

Initially install and tighten CA and CMA by hand. Complete tightening operations using a wrench. Failure to follow this procedure may damage threads.

4. Invert CA and attach to top of CMA.
5. Remove caps from sample inlet and outlet ports of CMA.
6. Open sample extraction valve on CA and sampling valve on CMA.
7. Slowly open sample extraction valve on sample cylinder and allow precharge to purge sampler.
8. When precharge is depleted close sample extraction valve on sample cylinder.
9. Close sampling valve on charging manifold.

CAUTION

Liquid oxygen flow will be obtained at whatever pressure is present at sample source. Do not upset operation of O_2 N_2 producer in an attempt to obtain a certain pressure for extracting sample.

10. Build up pressure at sample source to 30 psig or as close to 30 psig as possible.
11. Connect sampler fill hose assembly to sample source.
12. Open liquid valve to purge fill hose.
13. Close liquid valve.
14. Connect fill hose to CMA.
15. Slowly open liquid valve and permit liquid to flow until a steady stream is observed from outlet fitting.
16. Open sampling valve to allow liquid to enter sample cup assembly for 2 minutes.
17. Close sampling valve.
18. Close liquid valve.
19. When liquid stops flowing from outlet port, disconnect fill hose from liquid sample source and allow residual liquid to drain from charging manifold.
20. Disconnect fill hose from charging manifold.
21. Open extraction valve on cylinder assembly to permit sample liquid to flow into cylinder.
22. When cylinder assembly pressure gage stabilizes at 1300 to 1800 psig, close sample extraction valve on CA and open sampling outlet valve on charging manifold to vent manifold pressure.

CAUTION

If sample vent valve is not opened before disconnecting sample cylinder, trapped pressure will blow out the sealing ring on attachment port.

23. When manifold pressure is vented, disconnect cylinder assembly from the charging manifold assembly.

24. Replace all protective caps and close sampling valve on charging manifold.

25. Forward sample and accompanying paperwork to nearest approved testing facility.

550-8.6.5 CONTAMINANTS IN OXYGEN OR NITROGEN. A variety of contaminants could be in liquid oxygen or nitrogen produced by a cryogenic, air liquefaction and distillation process. The contaminant concentrations are usually much lower than the limits that would create risks of reactions with oxygen, toxicity to users, and plugging of equipment by water or carbon dioxide ice. Personnel responsible for production, storage and transfer operations should understand the importance of oxygen-nitrogen purity and the procedures for maintaining liquid oxygen-nitrogen quality.

550-8.6.5.1 Pure oxygen-nitrogen is odorless; therefore any odor detected during the odor test indicates contamination. The odor test is a simple on-site test which immediately provides a qualitative indication of contamination without waiting for results of off-site instrumental analysis. A contaminant's odor is sometimes distinctive enough to be a clue to identifying the source.

550-8.6.5.2 The contamination of product oxygen-nitrogen often comes from the intake air. Oxygen-nitrogen (O_2 N_2) producer operators have to be continually alert to the possibilities of contaminants being drawn by the air compressors from the weather vent intake and from within the ship through open compartment accesses. Air compressor compartment doors to O_2 N_2 plant spaces must be kept shut and opened only for personnel access. Other contamination sources are residual, cleaning solvent in the equipment due to incomplete purging and refrigerant R-22 from a leak within the air-refrigerant heat exchanger of a high-pressure O_2 N_2 producer.

550-8.6.5.3 In the liquid storage tank, contamination levels can become higher than those of the produced oxygen-nitrogen because the oxygen-nitrogen is continually boiling (evaporating) and leaving the less volatile contaminants in the tanks, which increase proportionally in concentration. Another way contamination levels increase is by back-diffusion from the atmosphere through the tank's vent piping. Back-diffusion is kept to a minimum by keeping a slight positive pressure within the tank and a continuous outward flow of vented gas controlled by the tank vent line's back pressure regulator. Normally, liquid oxygen-nitrogen contamination in the storage tank is kept low as the liquid is used and the tank is then topped off with fresh liquid that dilutes the contamination concentration.

550-8.6.5.4 Liquid oxygen is extremely sensitive to contamination by acetylene. Even very small quantities of acetylene in liquid oxygen can be hazardous. Acetylene can accumulate in the liquid oxygen if the gas is present in the intake air to the oxygen-producing plant. Acetylene may be in the intake air either as a result of nearby welding operations or because of the proximity of an acetylene manufacturing facility or cylinder storage area. Under certain extreme conditions, acetylene can also form in the high pressure air compressor as a result of the high-temperature breakdown of lubricating oil. To prevent any possibility of explosion, acetylene concentrations in liquid oxygen must be maintained at fewer than two parts per million. However, the acetylene level must be much lower than this to meet the aviators breathing oxygen requirement.

550-8.6.5.5 Contaminants that could be present in liquid oxygen are of particular concern if oxygen is to be used for aviators' breathing. Extremely high contaminant concentrations are potentially toxic. In addition, unusual or objectionable odors that are not readily identifiable can produce adverse physical and psychological effects on the user. Specification MIL-0-27210 and NAVAIR Technical Manual A6-332AO-GYD-000 describe aviators' breathing oxygen (ABO) requirements. The quality of oxygen to aviators is of prime concern, however decisions that will disrupt available oxygen for support of air operations should not be made hastily or on unfounded suspicions. Decisions such as stopping production or dumping storage tank contents should be arrived at by careful analysis and consideration of all possible alternatives. With guidance or direction from its respective Operating Forces administrative chain of command, each individual command should establish procedures to do the following:

550-8.6.5.6 Accomplish timely oxygen analyses, document all results and inform all concerned. Resample and report to all concerned when contamination is suspected or detected by analysis. Ensure ABO quality is within limits prescribed by NAVAIR technical manual A6-332A0-GYD-000.

550-8.6.5.7 Have every effort made by ship's force and air wing personnel to prevent the spread of contamination from oxygen transfers among storage tanks, service containers and user containers.

550-8.6.5.8 Determine if transfer to an ABO storage tank should be prohibited when contamination of oxygen from the producer has been verified by analysis of consecutive samples, or the contamination is severe or the source is not readily identifiable or controllable.

NOTE

If such a circumstance arises after product transfer to the tank was begun under normal operating conditions, immediately shut the producer's product valve. Then, if the contaminant is identified and determined to be transient in nature, establish flow to drain off and dilute the contaminated oxygen while maintaining liquid levels by controlled opening of the condensor drain or LP column drain valve. Appropriate precautions must be taken and drainage flow continuously controlled when the producer is operated this way. The product valve will be kept closed until sampling analysis results meet ABO standards.

550-8.7 PRESSURIZATION OF OXYGEN AND NITROGEN SYSTEMS WHEN OUT OF SERVICE OR LAYED-UP

550-8.7.1 PRESSURIZATION OF LIQUID OXYGEN AND NITROGEN STORAGE TANKS WHEN OUT OF SERVICE OR LAYED-UP. To prevent entry of contamination when a liquid oxygen-nitrogen (O_2 N_2) storage tank is not in service, and is empty, all valves must be shut and a positive pressure (25 psig minimum) must be kept in the tank. This pressurization excludes the cryogenic pump-and-vaporizer or charging unit and associated piping; see paragraph 3 below. The pressurization for a N_2 tank is with N_2 gas and for an O_2 tank is with either O_2 or N_2 gas; however, if ″hot work″ is to be done on the O_2 tank, then N_2 gas must be used. The positive pressure in the tank is attained by any of several ways.

a. When a tank is being drained to empty, shut all valves to retain pressure before the tank vents to zero (Note: Undrained liquid in the tank will vaporize as the tank warms and adds to the internal pressure; check the pressure periodically and vent as necessary to keep pressure below tank's relief valve setting).

b. Pressurize the tank by means of the ″emergency pressurization″ piping connection from the ship's flask(s) and distribution system (Note: If this is done when the tank is cold, the contained gas will expand and the pressure will increase as the tank warms; check the pressure periodically and vent as necessary to keep pressure below tank's relief valve setting).

c. Pressurize the tank with dry, oil-free N_2 gas from a portable cylinder, via a regulator (set pressure less than maximum rated, tank operating pressure), and hose attached to convenient, tank pipe connection, e.g., temporary fitting on full trycock (also, see note at b. above).

550-8.7.1.1 The retained pressure should be monitored frequently (at least every 2 hours) during the first 24 hours to ensure there is no leakage loss; leakage should be corrected (if leakage cannot be stopped, periodic or continuous repressurization must be done as necessary). Thereafter, retained pressure should be checked every 8-12 hours. Monitor pressure using the tank's pressure gage.

550-8.7.1.2 All isolation valves between the tank and the cryogenic pump-vaporizer charging unit must be shut, otherwise pressure can leak from the tank by the pump's piston packing or cylinder bleed passages (leakage might be quick or gradual, depending on pump design). For that reason those components and piping cannot be held in a static, pressurized state; but all valves (pump inlet, vent, etc.) must be shut. It is advisable, when utilizing pressurization method b. or c. as described above, to initially pressurize the pump-vaporizer charging unit and piping, and immediately shut all isolation valves. That provides a purge prior to the lay-up shutdown, and is helpful to the extent that pressure might be retained.

550-8.7.2 PRESSURIZATION OF GASEOUS OXYGEN AND NITROGEN DISTRIBUTION PIPING WHEN OUT OF SERVICE OR LAYED-UP. To prevent entry of contamination when gaseous oxygen-nitrogen (O_2 N_2) distribution piping or flask is not in service, all valves must be shut and a positive pressure (100 psig minimum, or the maximum operating pressure rating if less than 100 psig) must be kept in the piping or flask. The pressurization for N_2 piping is with N_2 gas and for O_2 piping is with either O_2 or N_2 gas; however, if ″hot work″ is to be done near O_2 piping, then N_2 gas must be used. The positive pressure is attained by either of two ways.

a. When distribution piping is becoming depressurized, either by user consumption or by intentional bleed-down, shut all necessary valves and stop the depressurization before required positive pressure is lost. Be sure to keep reserve pressure in the flask(s) so that piping can be pressurized when out of service or layed-up.

b. Pressurize the piping with dry, oil-free N_2 gas from portable cylinders, via pressure regulators, and hoses attached to appropriate piping connection fittings (either permanently or temporarily installed).

550-8.7.2.1 The retained pressure should be monitored regularly, using the system's pressure gages, to ensure there is no leakage loss; leakage should be corrected.

APPENDIX A.

GLOSSARY

Acetylides Highly explosive chemical compounds formed by the reaction between acetylene and various metals.

Adsorption The process by which gases and liquids physically adhere to the surfaces of solids.

Air Separation Plant Equipment for separating air into its major components (oxygen and nitrogen), usually by liquefaction followed by distillation.

Anode The positive electrode at which oxygen gas collects during the electrolysis of water.

Carbide Calcium carbide, a hard granular compound of calcium and carbon which reacts spontaneously with water to produce acetylene gas and lime.

Carboxide A gaseous mixture containing 90 percent by volume of carbon dioxide and 10 percent by volume of ethylene oxide; used as a fumigant.

Cathode The negative electrode at which hydrogen gas collects during the electrolysis of water.

Cavitation Formation of a gas pocket in the inlet chamber of a cryogenic pump resulting when the temperature of the pumped liquid rises above its boiling point.

Claude Cycle A method of liquefying air involving compression of the air and expansion of a portion of it through an expansion engine.

Cold Box An insulated enclosure containing all the low temperature components of an air separation plant.

Contaminant Undesirable foreign matter in a gas or liquid.

Converter, Aircraft Small, insulated container for liquid oxygen or liquid nitrogen, designed for installation within air craft.

Cryogenics The science that deals with the production of very low temperatures, particularly temperatures below -101°C (-150°F).

Dead-End Pressure The lowest pressure practically obtainable using a given vacuum pump, with the main suction valve closed.

Defrost The warming up of an air-separation plant to ambient temperature, usually to evaporate and remove volatile contaminants.

Desiccant A solid that is capable of drying a fluid by adsorption of both gaseous and liquid water.

Electrolysis The process of decomposing water into oxygen and hydrogen by passage of a direct electric current through the water.

Electrolyte The liquid (potassium-hydroxide solution) that carries the electric current during electrolysis.

Expansion Engine A reciprocating or rotary engine that extracts energy from compressed air in the Claude cycle, thereby refrigerating this air prior to liquefaction.

Freon A trade name of a group of halogenated hydrocarbons used as refrigerant gases.

Fusible Plug A safety device used on certain gas-cylinder valves consisting of a threaded plug, drilled and filled with a fusible metal that melts when the cylinder is exposed to high temperatures.

Genetron Same as Freon but made by a different manufacturer.

Heat Leak Heat that enters an air-separation plant or other cryogenic system because of inadequate design, poor insulation, or other defect.

Heat Pump A device used in air separation plants to transfer liquefied gas from a lower to a higher level by reducing its density through heating.

High Pressure Column
The distillation column of air separation plant in which pure nitrogen is produced. A typical pressure is 100 lb/^{2} g.

High Pressure Cycle
Same as Linde cycle.

Inert Gas A gas that does not react chemically with other substances. For shipboard fire protection applications, an inert gas must contain no more than 3 percent by volume of oxygen.

Isotron Trade name of a refrigerant gas equivalent to Freon but made by a different manufacturer.

Joule-Thompson Expansion
Expansion of a high pressure gas through a valve or orifice to reduce temperature, as in the Linde cycle.

Linde Cycle A method of liquefying air, employed in all shipboard air separation plants, using Joule-Thompson expansion, heat exchange, and auxiliary refrigeration.

Low Pressure Column
The distillation column of an air separation plant in which pure oxygen is produced. A typical pressure is 5 lb/^{2} g.

Low Pressure Cycle
Same as Claude cycle.

McLeod Gage A mechanical vacuum gage widely used as a primary standard.

Micrometer A unit of pressure equivalent to 1/1000 millimeters (0.0004 inches) of mercury (formerly, micron).

Molecular Sieves
A solid adsorber for water and carbon dioxide.

Monoethanolamine (MEA)
An organic, water-soluble liquid that is used to absorb carbon dioxide from its mixture with air and that releases carbon dioxide upon heating.

Nonequilibrium Gas Pressure
The gas pressure generated above the liquid in a cryogenic storage tank by partial vaporization in the pressure building coil. This pressure is in excess of the vapor pressure corresponding to the bulk temperature of the liquid.

Oil-Gas Gas that has been compressed using a nonlubricating process.

Oil-Tolerant Gas
Compressed gas containing traces of compressor lubricating oil.

Orsat Analyzer
A laboratory device for determining the composition of a gas by measuring the shrinkage of a known initial volume of the gas as each component is removed.

Packed Column
A vertical column filled with small inert particles that may be regularly or irregularly shaped. The column serves to bring about intimate contact between a gas and a liquid stream, for purposes of either absorption or distillation.

Parts Per Million (P/M)
A unit of gas concentration, referring to the number of volumes (or weights) of a given material contained in one million, equal to 0.0001 percent.

Permanganate **Refers to potassium permanganate (KMnO4), a purple, crystalline material which reacts with and removes many impurities from a carbon dioxide stream.**

Potassium Hydroxide (KOM)
A strongly alkaline chemical that is used, in a 30-percent water solution, as an electrolyte in all shipboard electrolytic oxygen generators.

Powder, Evacuated
A medium used for insulating cryogenic storage tanks in which a surrounding space is filled with a nonconductive powder and maintained at high vacuum.

Pressure-Building Coil
An uninsulated section of tubing connecting the drain and vent connections of a cryogenic liquid-storage tank. Liquid admitted to this coil is vaporized by room heat and increases the nonequilibrium gas pressure within the tank.

Purity **The percent by volume of the major constituent in a gas.**

Quinquennial Tests
Certain physical tests conducted on compressed gas cylinders at 5-year intervals.

Reactivation **A process for removing adsorbed moisture, hydrocarbons, or other contaminants from air dryers and purifiers by purging with hot, dry gases.**

Reboiler **The section of a cryogenic distillation column in which the condensing tubes are surrounded by boiling liquid oxygen.**

Reflux **The process in which liquid moves down a distillation column and comes into close contact with vapors rising up the column, thereby stripping them of their less volatile components.**

Silica Gel **A granular, adsorbing material used to dry high and low-pressure gas streams.**

Soda Lime **A granular mixture of lime and caustic soda used to remove carbon dioxide from air streams.**

Spectrophotometer, Infrared
An instrument used to determine the concentration of trace contaminants in gas streams by measuring the absorption of infrared radiation resulting from such contaminants.

Sub-Cooling **The cooling of a liquefied gas below its boiling point, usually to prevent evaporation losses and pump cavitation.**

Thermocouple Vacuum Gage
A vacuum-measuring device that makes use of the correlation between a change in the thermal conductivity of a gas and a change in its absolute pressure.

Tray Column **An absorption or distillation column containing evenly spaced, horizontal trays rather than packing. The trays are perforated or slotted and carry reflux liquid through which the rising vapors are bubbled.**

Tricresyl Phosphate
An oily, relatively nonflammable liquid extensively used as a lubricant in vacuum pumps that service liquid oxygen storage tanks.

Ucon **Trade name of a refrigerant gas equivalent to Freon but made by a different manufacturer.**

Vapor Barrier **A gas-impervious coating or casing applied to unevacuated cryogenic insulation to prevent atmospheric moisture from entering the insulated space and condensing on cold, internal surfaces.**

Waste Gas **Impure low-pressure gas (from the distillation column of an air separation plant) that is discarded to atmosphere after it has extracted heat from the fluids being cooled. Waste gas is also used, after heating, to reactivate high pressure air dryers, purifiers, and carbon dioxide filters. Reheated, in succession, to achieve low-level refrigeration. This cycle is employed in the operation of cryogenerators.**

REAR SECTION

NOTE

TECHNICAL MANUAL DEFICIENCY/EVALUATION EVALUATION REPORT (TMDER) Forms can be found at the bottom of the CD list of books. Click on the TMDER form to display the form.